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THE HOME ELECTRICIAN

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THE HOME
ELECTRICIAN

BY

F. J. CAMM

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PREFACE TO SECOND EDITION

THIS edition has been fully revised and brought up to date by adding an additional chapter on the ring circuit. This system is the result of considerable research and has resulted in the production of a method of house wiring which is easily installed by the amateur, is cheap, and enables an unlimited number of appliances to be connected to one circuit. New matter on earthing connections and earth leakage trips is also included.

PREFACE TO THIRD EDITION

IN revising this edition I have included an additional chapter on how to bring your existing power points up-to-date. With the old type of power point you could not obtain complete interchangeability as with 13-amp. universal sockets. The method of conversion is fully explained in this new chapter, which appears on page 201.

A. T. COLLINS

PREFACE

THIS Handbook deals with the installation, upkeep, overhaul and repair of most electrical apparatus used in the home, with additional chapters on house-wiring.

It is a book for the handy-man who prefers to do jobs for himself.

Its publication has been prompted by the increasing use of electricity and electrical labour-saving devices in the home. Most of the troubles which occur are of an elementary nature, and no great experience or technical knowledge is required in order to put them right.

Such technical knowledge as is necessary can be gathered from a perusal of these pages, and where precautions are necessary such are carefully explained in the text.

The installation of all electrical apparatus and the wiring of houses are governed by I.E.E. regulations, and before any major alterations to house-wiring are made involving the appropriate electrical undertaking's mains, that authority should be consulted.

There is nothing in this book which warrants such a course. If the instructions are carefully followed there is no risk of accidents or shock. Particular caution is, of course, necessary when installing electrical apparatus in bathrooms or in other places where there is running water or dampness.

F. J. CAMM

I am indebted to the publishers of "Practical Mechanics" for permission to use information and illustrations which appeared therein.

I

ABOUT ELECTRICITY

In order that electrical apparatus can be correctly installed, repaired and safely and economically run, an elementary knowledge of electricity is necessary. This chapter is, therefore, devoted to an elementary explanation of electricity as it affects the home.

Most houses to-day are wired for alternating current (A.C.), drawing their power from the grid. In only very few districts is direct current (D.C.) employed. Within a few years the whole country will change over to A.C.

Hence, when purchasing electrical apparatus, it is necessary to state the voltage, and the frequency, if your house is wired for alternating current. Most voltages are between 200 and 250 A.C., whereas direct-current voltages vary from 100 to 200. As its name implies, A.C. refers to a current whose direction of flow surges first in one direction and then in the opposite direction at a regular period or frequency. One alternation is referred to as a cycle, and when we speak of 50-cycle A.C. mains, we mean that there are 50 alternations per second.

Apparatus designed to run on one frequency will not run on mains of another frequency, even though the voltages are the same. Fortunately the frequency of most mains in this country has been standardised at 50 cycles per second.

Plugs and Sockets or Points.—You will notice throughout your house that some of the plugs and sockets, or points, as they are commonly termed, are larger than others. Usually only three sizes are employed—2 amp. for small apparatus taking very little current, such as electric clocks, 5 amp. for lighting and 13 or 15 amp. for electric fires and other apparatus taking a fairly heavy current. It is the intention within the next few years to standardise all plug points, and for all plugs to contain a fuse of a value according to the current consumption of the apparatus to which it is attached.

The current-carrying capacity of the wiring to these various points needs to be kept well in mind, for if apparatus which takes more than 5 amps. is connected to, say, a 5-amp. point, the wiring will become overheated and the fuses will blow. All wiring points have a fuse inserted. The fuses are really safety-valves, and consist of a piece of fuse-wire mounted on porcelain and inserted in the switch-box, usually located close to the meter, the current-carrying capacity of which is decided by the circuit in which it is connected.

The use of fuse-wires of the correct value, such as 5 amp., 15 amp., etc., is therefore important. Wire of the correct value is available from all stores on clearly marked cards. A large amount of electrical apparatus is sold without plugs and it is left to the user to connect the plug. He must therefore decide what current in ampères the apparatus will take. This is easily ascertained by remembering Ohm's Law, which, simply expressed, is: Current equals voltage divided by resistance, or, expressed as a simple formula:

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}}$$

Also power in watts is found by multiplying voltage by current.

From this simple formula either current, resistance or voltage can be found, provided that the other two are known. For example, suppose an electric fire consumes one unit or kilowatt (1,000 watts), we know by dividing 1,000 by the mains voltage, say 250, that the fire is consuming 4 amps., and could be connected to a 5-amp. point. Usually electric fires are connected to 15-amp. points.

Symbols.—Symbols are given for current, voltage and resistance. The symbol for current is I, the symbol for voltage is E, and the symbol for resistance is R, so Ohm's Law becomes: $I = \frac{E}{R}$. From this simple equation it is obvious that the voltage can be found by multiplying the current by the resistance ($E = I \times R$), and the resistance is given by dividing the voltage by the current $\left(R = \frac{E}{I}\right)$. In all the equations the three terms must be in the units of the respective measurements—namely, I in ampères, E in volts and R in ohms.

Example: If the voltage is 6 and the resistance is 3 ohms:

$$\text{Current} = \frac{6}{3} = 2 \text{ amps.}$$

$$\text{Resistance} = \frac{6}{2} = 3 \text{ ohms.}$$

$$\text{Voltage} = 2 \times 3 = 6 \text{ volts.}$$

The points in most modern houses make use of 3-point plugs and sockets. The third pin is for earthing. For safety purposes, and to prevent shocks when touching any metallic part of the electrical apparatus, it is important that it should be earthed. It is realised, of course, that older houses are still wired for two-pin points.

A unit is 1,000 watts, or a kilowatt, as stated. A kilowatt hour means 1,000 watts flowing for 1 hour.

The charge for a unit of electricity in this country varies according to the district, but, knowing the cost of a unit, it is easy to estimate the cost of running any particular piece of electrical apparatus. A 100-watt lamp, for example, uses one tenth of a unit.

Electricity Charges.—There is often some misunderstanding among householder consumers of electricity concerning its cost, or different costs, for what they might call the same commodity.

The charge for lighting may be anything between 4*d.* and 8*d.* per unit, whilst for heating, cooking and other domestic uses, the charge may be about one penny a unit. On the other hand, there may be a fixed low charge per unit for whatever purpose the electricity is required, whether it be for lighting or power purposes, together with a fixed annual or quarterly payment.

To help towards an understanding of these different prices charged per unit, it must be realised that the costs of electricity are not measured solely by the amount used, but are largely influenced by the rate and time of use, as well as the purpose for which the consumer requires the electricity. The reason why these latter points influence the cost of electricity will be understood if we consider the Electric Supply Authorities' point of view regarding the generation and distribution of electrical energy. Lack of proper information concerning tariffs and flat rates may cause the consumer to restrict the use of electricity in the home because of mistaken ideas about costs—or no idea at all, in some cases.

To enable us clearly to understand the cost of electricity, let the buying of electricity be viewed more in the light of paying for a service than that of buying a commodity.

Since electricity in the form we require it cannot be economically stored on a commercial basis, it follows that the whole power consumption required by the multitude of consumers at any instant from any supply station must be generated and transmitted direct to the consumer. This means that the station equipment, cables, etc., for transmission must be large enough to meet the biggest load that may be required from it, irrespective of this big load being required only at certain times—say in the evening, when every consumer wants power for light.

The greatest expenses in the generation of electricity are the initial costs of machinery, buildings, cables, meters, etc., interest on money invested on these, labour, rates and insurance. These items are but little affected whether the consumers' loads are light or heavy. The remaining expenses, covering the cost of fuel used for the operation of the machinery, do, of course, vary with the amount of energy produced, for which the consumer pays.

It is obvious, therefore, that with these essential conditions, the supply authorities must have some income from the vast body of consumers, something by way of a rental for the equipment necessary to meet these conditions. When sufficient energy is consumed to meet this initial rental, it follows that all energy required over this amount can be supplied at comparatively lower rates.

It will be seen from this that customers who require energy only for lighting purposes must pay the highest rate for it. They use a comparatively small amount individually, and require it at that time when the load from the supply station is at its heaviest—during the lighting period of the evening, when everyone wants energy for light. As far as the "lighting only" consumers are concerned for the remainder of the twenty-four hours of the day the generating equipment need not be there. During these hours they take no load from the station, and consequently there is no revenue for the supply authorities.

Now, the consumer who, besides taking energy for lighting, takes it also for heating, cooking and some of the many other electrical domestic requirements, helps to build up a load from the supply during the day, when the load is only light compared with the evening load.

The supply authorities, therefore, in the hope of levelling out the demand for electricity, offer this type of consumer a reduced rate, which consideration introduces tariffs. This encourages the progressive use of electricity in household power appliances, helps to get away from restricted lighting to ample illumination, and aims at the completely electrified house. At the same time, it is an inducement to users of electric light only to extend the use of electricity to some of the many other household uses, and so benefit by the reduced rates.

Having seen why the prices for power units are cheaper than those for light, it is advantageous now to consider the general methods of charging for electrical energy.

Standard Method of Charges.—There are two standard methods offered to household consumers: one is the flat rate per unit—that is, one rate per unit for lighting and another rate for heating, cooking, vacuum cleaners, wireless, etc., and other uses coming under the heading of power. This method complicates the house wiring and circuits, in that two meters have to be supplied, one fairly small for measuring lighting units at a relatively high price, and a larger meter for the power units at a lower price. Furthermore, the wiring and plug-points for power must be kept distinct from the lighting wiring, thus involving two separate main circuits. Under this flat-rate system an average price for lighting units might be 5½*d.* and for power purposes about 1⅞*d.*

The other method of charging offered to consumers—and it is becoming increasingly popular in medium-sized houses—is referred to as the "domestic", "two-part", or "all-in" tariff. It consists of a fixed annual charge, related to the size of the house or the amount of electrical apparatus installed, plus a small charge per unit used, usually between ¾*d.* and 1¼*d.*, for whatever use the electricity is needed.

With this method only one meter is required and consequently only one system of wiring, as all the units are at the same price. This is a great convenience, especially in the smaller houses, where a light-duty plug can be connected to the lighting circuit at any convenient outlet and used for any of the small appliances without the need to consider whether the supply is charged for at a higher lighting rate or a lower power rate.

The annual charge alluded to above is usually calculated so that, together with the revenue from normal lighting at the unit rate, they produce the yearly amount which would be expected from a consumer who uses light only at the standard flat rate.

In order to understand fully why the cost of operating various electric lamps and apparatus differ, it is necessary to understand the three important electrical units. They are the volt, the ohm and the ampère (abbreviated to amp.). The former is the unit of electrical pressure, the second is the unit of resistance, and the third is the unit of current. A lamp or any other electrical apparatus possesses the property of resisting to a certain extent, the filament, the heater of a fire, or the windings of an electric motor providing the resistance, and the passage of the current through the resistance causes a displacement of the molecules from which the resistance is made, which results in a rise of temperature. If a very thin wire is used, and a high voltage is applied, the wire may become red hot, thus providing a heating element such as is used in an electric fire or hair-drier. Special wires are employed in this type of apparatus to avoid continued burning out which would arise with ordinary thin copper wires. If the resistance of a device and the voltage of the mains supply are known, it is possible to ascertain the current which will flow through the device. Similarly, if only the current and voltage are known, the resistance may be ascertained. This simple formula is known as Ohm's Law, which is explained earlier in this chapter.

As, however, the consumption of electrical apparatus is registered in units, it is necessary to know one another factor—namely, the wattage. The product of the voltage and the current gives the wattage, and there are 1,000 watts to 1 kilowatt (kW.). One unit consists of one kilowatt hour, and thus, if we have an electric fire, for instance, rated at 1 kW., we know that in one hour it will consume 1 unit of electricity. From these figures it is thus possible to calculate its resistance and to ascertain other values which may be needed when modifying existing apparatus.

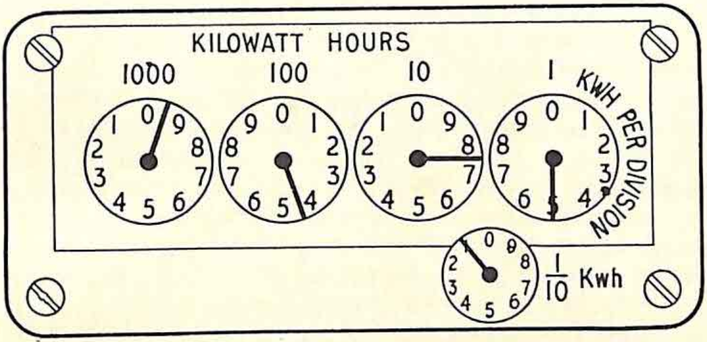

FIG. 1.—Reading an electricity meter. The above reads 9475.

For example, an electric fire consuming 1 unit or 1,000 watts per hour takes a current of 4 amps. when connected to 250-volt mains, or 5 amps. when connected to 200-volt mains.

It is important to remember that all electrical apparatus must be selected to suit the mains to which it is to be connected. You must not connect 200-volt apparatus to 250-volt mains, for example, as it would probably burn out.

How to Read Your Meter.—The meter is quite easy to read, and you can keep a record of daily or weekly consumption of electricity. In reading the meter ignore the small dial marked 1/10 kWh., and read the other dials from left to right. The meter illustrated in Fig. 1 shows 9,475 units, and by subtracting your previous reading, the number of units used in the meantime will be apparent. The dial hand should always be read as indicating the figure it has last passed, and not the one to which it may be nearest.

II

RULES AND REGULATIONS

BEFORE any attempt is made to tamper with the mains supply, or to fit any additional apparatus, it is essential to remember that there are certain regulations applying to the use of electricity.

The Institution of Electrical Engineers deprecates encouragement being given to unskilled persons to carry out *major* electrical installations, and it is a Home Office Regulation that no one save an authorised person over the age of twenty-one be allowed to interfere with an electrical installation.

If you wire up your own house, presuming you have the necessary skill and knowledge to do so, the installation has to be approved by the Inspector for the particular local electrical authority, who would decline to connect the installation to the mains if it did not comply with the regulations. Expensive testing equipment is necessary to test an installation, and a charge for such a test may be made.

When taking over an old house it is always desirable to obtain expert advice as to whether the existing installation complies with modern requirements. The local electrical authority will undertake the inspection for you. The electrical installation of a modern small house is explained in Chapter III, and such information is given to help the householder to understand the principles and practice of it.

As a guide to the householder who is considering an electrical installation, I give a summary of the important points covered by regulations, so that he may decide whether such an installation is practicable, and whether the building in its present form enables such regulations to be complied with. These specify that no modifications may be made, nor apparatus added to the existing fitments, until permission has been obtained.

Certain fire and other insurance authorities are guided by these recommendations, and in the case of infringement will consider a policy null and void. These regulations are not laid down in any sense as hardships, but are provided in the interests of the general public safety.

Open-type switchboards must be placed only in dry situations and in well-ventilated rooms, and if used in the vicinity of batteries the arrangements shall be such as to prevent access of acid fumes to the switchboards.

Every switchboard installed in a damp situation, or where inflammable or explosive dust, vapour or gas is likely to be present, shall be of the enclosed type.

Every lighting fitting shall be controlled either by a switch or switches, or, subject to recommendation, by a socket outlet and plug, so placed as to be readily accessible. The recommendation is as follows: Where the supply is direct current, not more than two socket outlets rated at 5 amps. or less shall be fitted in any room without individual or collective switch control being provided in the same room for all such socket outlets in excess of two; and each socket outlet having a rating exceeding 5 amps. shall be controlled by a switch immediately adjacent or combined therewith.

Where the supply is alternating current, a socket outlet need not be controlled by a switch in the final sub-circuit to which it is connected.

A cut-out containing a suitable fuse-link having a current rating not exceeding 3 amps. shall be inserted in each pole of the secondary circuit from a transformer or converter having an output not exceeding 30 volt-amps. which energises electric bells or similar signalling apparatus, and also with such a transformer or converter of larger output than 30-volt-amps. whenever necessary for the protection of the secondary circuit. For an electric motor, the maximum current rating of the cable shall be deemed to be the rated full-load current of the motor.

Every cable, flexible cable and flexible cord shall comply, as regards its insulating material and protective covering, with the requirements laid down, which give details of the requisite rubber or other coverings which must be used for different loads and with various types of apparatus.

A ceiling rose shall not be used on a circuit the voltage of which exceeds 250 volts. Not more than two flexible cords, each of which shall comprise not more than three conductors, shall be attached to one ceiling rose unless the ceiling rose be specially designed for multiple pendants.

Where a step-up transformer, other than an auto-transformer, is installed on the consumer's side of the consumer's terminals and forms part of his installation, a multipole (linked) switch shall be provided for isolating the transformer from the supply.

In places where petrol-driven conveyances are stored or repaired, every current-using appliance other than a portable appliance shall, unless of a flame-proof type, be fixed at a height of at least 4 ft. 6 in. above the floor level of the room.

In every room containing a fixed bath, all metal forming part of the electrical equipment shall, except in certain particular cases, be either completely shielded by non-conducting material or concealed within walls, floors or ceilings.

Every transformer, converter or other device by means of which energy from a public or private supply system is furnished to an electric bell and/or similar signalling circuit shall comply, as regards its design and construction, with the following clauses:

The primary and secondary windings (if any) shall be separate throughout, provided that this requirement shall not apply where the secondary circuit and apparatus comply with the requirements which are applicable to lighting, heating and power circuits.

The primary (input) terminals shall be suitably separated (electrically and by adequate spacing) from the secondary (output) terminals, and shall be so marked as to be easily distinguishable therefrom.

The case (if of metal), and its core or frame, shall be provided with a suitable terminal to which the earth continuity conductor may be connected.

III

THE INSTALLATION EXPLAINED

Although, as explained in Chapter II, it is against regulations to *tamper* with an installation, and unwise for the unskilled to wire a house, it is helpful to understand the system used in house-wiring. All lighting or other points are connected in parallel with the main feeds of the supply, one lead in each point being broken by a switch to allow of the control of the light or point. The multi-wires which often look so complicated to the amateur are rendered necessary by the method used in passing the current from point to point without returning to the main feed for each particular circuit; a glance at the schematic drawing (Fig. 2) will convey the whole idea. Before getting to practical work the electrician must first arrive at the number of points required, the power at each point, and—the last and most important item—what the total current will be

Room.	Lights.	Plug-points.
Reception	1 60 watts	—
Dining	1 60 ,,	—
Bedroom	1 40 ,,	—
,,	1 40 ,,	—
Kitchen	1 60 ,,	1 500 watts
Universal point for cleaner, etc.	—	1 250 ,,
	260 ,,	750 ,,
	260 750	
Total	1010 watts	
Using the method as explained . Suggested mains as explained .	$\frac{1010}{230} =$	4·4 amps. approx.

Room.	Switches.	Ceiling Roses.	Plugs and Sockets.	
Reception	1	1	—	—
Dining	1	1	—	—
Bedroom	1	1	—	—
,,	1	1	—	—
Kitchen	1	1	1	—
Universal point	—	—	1	—
Ironclad and fuses	1	—	—	—
Connection box	—	—	—	1
Lamp holders	—	—	—	5

1 Mounting board for main switch, 2 blocks, 5 wooden switch-boxes.

Fittings may be obtained in 5 amp., 10 amp., 15 amp.

No. of Strands.	Wires all Types. Diameter of each Strand.	Current in Amps. Maximum.
1	0·044	3
3	0·029	5
7	0·036	15

for the installation, and upon this last will depend the materials required.

The information given will not, of course, suit all houses, and the electrician will be called on to make his own list to suit the circumstances. The information is therefore intended to show how a list is compiled; this will apply to all the tables, etc., given, but whatever the requirements, the method remains the same.

Deciding the Total Current.—The current passing through the system in ampères may be found by adding the wattage of each point and dividing the total by the voltage of the main supply. On page 20 is given a list for a suggested installation.

Having given the method by which the total current is ascertained, the electrician decides upon the materials list (See table above), and it must be kept in mind that the rating of the materials should be to the nearest obtainable value

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above, and not below, the total current figures. As in the example installation, it would be 5-amp. fittings, this also applying to the cable list.

Three types of cable are in commercial use to-day, and any one of these may be used and will comply with the regulations of all concerned, including insurance companies, the types being: braided cable, which must be enclosed in metal tubing; lead-covered cable, the metal covering of which is supplied by lead placed over the insulation by the cable manufacturers; and tough rubber-covered cable, this last consisting of a cable with heavy covering of rubber over the inside insulation and being known as "cab-tyre".

As a matter of interest to those wishing to understand domestic house wiring as is now standardised for all small houses, it is helpful to trace out the wiring of a small house, and the diagram shown in Fig. 2 will assist. The first part to study is the ironclad switch carrying the fuses. This is usually placed as near as possible to the meter, and as a rule the meter and ironclad switch are placed under the stairs. The ironclad is mounted on the switchboard with the fuses at the top. In certain cases it is necessary to have a fuse in every lead, but for normal house wiring the diagram (Fig. 3) is typical.

You will find that most of the wiring commences from some central point at the top of the house, from which the distribution to the rooms is made. It will be found in most cases that the wiring proceeds under the boards in the various rooms, and nowadays quite often the top of the stairs is selected as the central point, allowing the wires for downstairs to pass under the floorboards. The twin cable passes to the ironclad switch. The wires are usually hidden from view, and are thus protected and do not disfigure the rooms. The cable may be let into channels in the wall. If the house is being wired subsequent to its building, other methods of wiring are employed, and it is not possible to make such a neat job of it as when the house has been designed in the first case for electric lighting and power. Those readers who are considering having their house wired for electric light should remember that this can be quite easily and cheaply carried

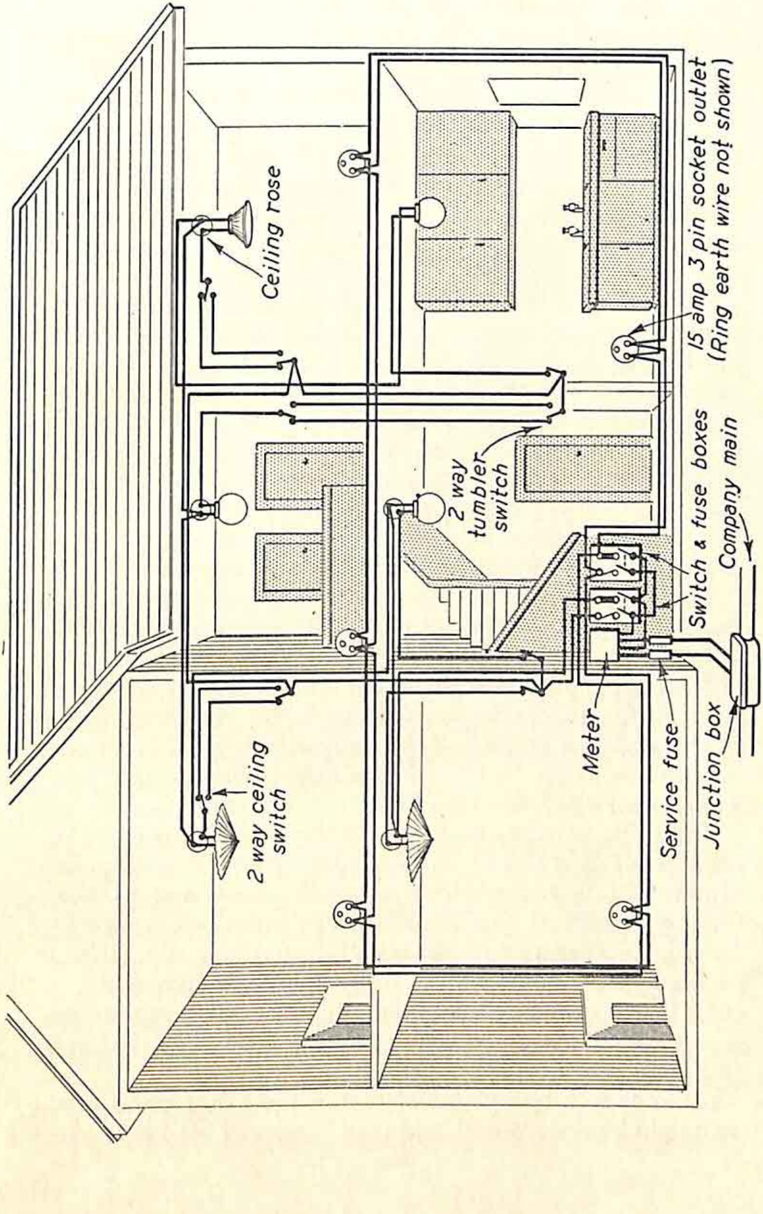


FIG. 2.—Typical wiring system of a small modern house.

out without the extensive work necessitated by removing the plaster or the floorboards. Electricians usually charge so much per point and so much per foot of wiring.

The general practice is to place the light-switches on the wall just inside the door, and where the doors of two rooms meet at a partition wall switches can be placed one on each side of the wall exactly opposite each other, thus allowing the use of one channel for the two switches; where this cannot be done a channel is provided for each switch, but the method will be the same.

At the point selected, a channel is cut from the floor to the ceiling in the upstairs room about an inch wide and the depth of the plaster; this channel will carry the cable for the switches and also the feed to above the upstairs ceiling for the light-points. At a suitable height the channel is enlarged into a square hole just large enough to take the wooden switch-boxes. If the lighting switches are placed opposite each other on a partition wall, a square hole only will be required for the box, and a small hole, just large enough for the cable to go through, carried through the brickwork.

The channels for the downstairs switches are cut down from the ceiling to a height of 5 ft. from the floor, and the holes for the boxes provided in the same way as those upstairs, and, with the exception of boring a hole through from the channel, for the downstairs switches to the upstairs.

The Lighting Points.—All wiring will proceed from the distribution point to the various lights and switches. We will explain the downstairs first.

The cable usually employed for the light-points must be capable of carrying 3 amps., although a lighting point cannot possibly require this amount of current; and, further, for this concealed wiring single cable may have been employed, to do away with the use of insulating boxes. It will be found that, commencing with the distribution point, a cable is laid to the lighting point, via the floor, and that the wire to the next room may proceed from that lighting point.

It can be seen by a glance at Figs. 4 and 5 how one side of each light has been wired, and how the circuit has been completed via the switches. To get to the switches the wire must pass down the channel to the lower room and back again from the switches, so going again to the feed-point; the cable is laid to the channel downstairs, and passes through

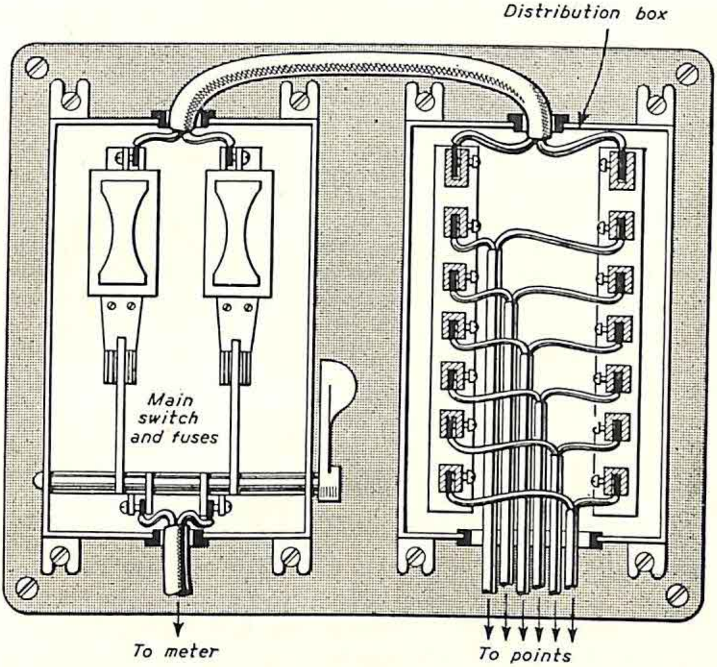


FIG. 3.—One arrangement of main switch, main fuses and distribution box or bus-bar chamber, as used for small domestic installations. The wiring from the distribution box is lead covered or tough-rubber insulated. In many installations the distribution box is replaced by a fuse-box, a separate fuse being provided for each two or three points. In some cases each lead must contain a fuse.

the ceiling down the channel to the switch. Now, this is to serve the two switches, therefore connection is provided from one to the other by means of a short piece of cable through the hole in the wall.

One side of each of the lighting switches will be connected to the light-points and a length of the 1/0·044 will have been laid from each light-point down the channel and connected to each of the respective switches, the cable for room 2 being passed through a hole in the wall.

The upstairs wiring is exactly the same as the down, and all that is done is to repeat the whole operation over again, the main leads in this case coming from the top of the stairs and going up the channel from the floor to the roof.

The leads for the upstair switches pass through a hole in the switch box which is fixed into the bricks by means of plugs. The switch, of course, is fixed into this box. It should be remembered that the switch is mounted in the live wire—not in the earth return.

The top part of the house is finished in the same way as the bottom, and the electrician, having connected up the various points, finds himself with an accumulation of wires at the top of the stairs; the distribution point consisting of the main feed (twin cable) and one wire from each light-point and also one wire from each switch.

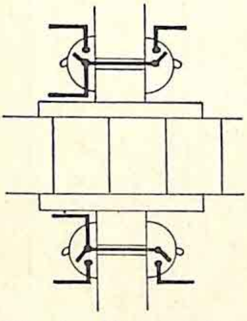


FIG. 4.—Showing how two switches in adjoining rooms may be interconnected.

The electrician sorts these out into two bunches—the light-points and the switches respectively—and he does this before closing the wall channels, and before the floorboards are fitted.

Of course, this work is carried out before the installation is connected to the mains, as the whole system has to be tested and passed by the inspector of the local authority. It is tested at the normal working voltage.

The Distribution Box.—The distribution-box arrangement is shown in Fig. 3, where will be seen the main switch, main fuses and the distribution box or bus-bar chamber as are used for small domestic installations. The wiring from the distribution box is lead-covered or tough-rubber insulated (cab-tyre).

In many installations the distribution box is replaced by a fuse-box, a separate fuse being provided for each two or three points. The limiting number of points for each 5-amp. fuse is ten, allowing an average (for safety) of 0·4 amp. or 100 watts per point (at 250 volts).

The distribution box is fitted in an accessible place and not under boards; as previously mentioned, the fusing arrangements will depend on the type of installation and total load. The plug-points proceed direct from the main switch, the universal point usually being mounted under the stairs near the main switch.

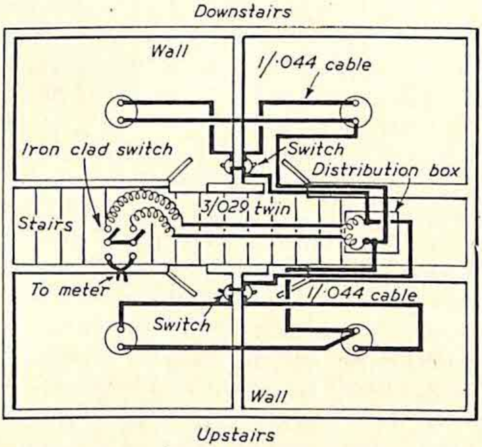


FIG. 5.—A typical wiring diagram for a light, showing how the circuit is completed via the switches.

Rose Fittings.—If the electrician has used ordinary ceiling roses, these will be screwed to the ceiling and a hole made for the wires to pass through the terminals; should, however, the position selected for the rose be between two rafters, a piece of board is cut to fit tightly between the rafters to enable the screws to bite into it. The ends of the flex for the lamp-holder are separated, passed through the hole in the rose, and tied before connection is made to the terminals to take the weight of the lamp; it is not safe to trust to the wire fixed to the terminals alone. If the electrician has fitted all-metal roses, such as are used for hanging bowls, the flex will be joined to the cables by means of insulated connectors, and in this case the weight will be taken by knotting the flex until it cannot pass through the hole in the metal rose.

IV

POWER WIRING EXPLAINED

THE householder considering the installation of all-electric power should endeavour to understand the methods of calculating the cost, even though he does not intend to make the installation himself. More and more householders with electric light installed are changing over to all-electric power now that modern devices in the form of cookers, irons, hair-driers, sewing machines, refrigerators, fires, fans, vacuum cleaners, electric clocks, as well as radio and television sets are available. Certain of the devices can, of course, be run from the house lighting circuit, as they take very small current. Providing that any particular sub-circuit is not already "loaded" to its maximum rating (usually 5 amps.), such devices as radio sets and electric clocks can be connected to it by means of an adaptor, if the point is already in use for another device. The local authority will advise you as to whether the particular circuit is suitable to supply the current for an additional device. Electric fires, vacuum cleaners, etc., must not be connected to the lighting circuit, but to a power point, providing that the device does not take more than 15 amps. Cookers or apparatus requiring more than 15 amps. necessitate a special circuit.

Calculating the Current.—Wattage divided by voltage will give the ampères passing in any circuit, whatever it may be, and by way of an example let us take the case of an electric cooker rated by the makers at 5 units (B.O.T. unit = 1,000 watts), and we will assume that the local supply is 200 volts, therefore

$$\frac{\text{watts}}{\text{volts}} = \frac{5{,}000}{200} = 25 \text{ amps.}$$

The best way to understand the question of installation is to wire an imaginary house. This will give an idea of the method of finding quantities of materials needed, but of course each electrician makes his own list, according to the particular house and the wiring to be done.

Room.	Points.	Apparatus.	Wattage.
Reception .	1	Fire	2,000
Dining . .	1	,,	2,000
Bedroom .	1	,,	1,000
,, .	2	Fire and water-heater	4,000
Kitchen .	1	Cooker	3,000
	6		12,000

We now know that our total load will be 12,000 watts, and assuming a supply voltage of 250, by using the method given previously, the total current flowing, if all apparatus be in use at one time, will be 48 amps.; it must therefore follow that the main switch and distribution equipment must be capable of carrying this current, and further, all main switches should be of the Ironclad type.

A list is given below that will apply to most installations:

List of Materials.
Mains switch and fuses, Ironclad type.
Combined plug-switch.
Wooden mounting-blocks.
Cooker, fires, water-heater.
Lamp-holder, batten-mounting type.
Ironclad switch.
Lamp-holder, mounting type.
Mounting-boards, wood.
Distribution box, Ironclad type.

All plugs must be of the three-pin polarised type. Each socket must have an earth wire.

Wiring.—Twin cable is used throughout, with the exception of the cable from the water-heater control switch to the actual heater, and this will be triple cable, to allow for heat changing, which will be explained later.

The main switch is, of course, connected to the distribution box by means of a heavy cable, one end being connected to the switch above the fuses. This will be at the top, the other end being connected to the main terminals on the distribution box. It will be found that the terminals at the bottom of the switch are connected by means of a heavy cable to the meter. It is connected to the latter by the Supply Company, and it is illegal to tamper with this. It will also be found that all wiring from that point onwards proceeds either under the floorboards or is otherwise concealed by convenient means, and is well protected against risk of fire or damage. The usual position for the plug-switches is on the skirting-board and, for a fire, near the fireplace, and the cable proceeds from the distributor box to the desired point. An examination of Fig. 3 makes clear the usual connections. It will be appreciated that this diagram and this information are given for purposes of explanation only.

Three-pin plugs must be of the polarised type, and each socket must have an earth wire.

For all ordinary purposes of explanation an electric cooker is the same as a fire, with the exception that the element cannot be seen and also that by arrangement of switching the amount of heat can be regulated. As it is impossible to see whether the cooker is on or off, some means of visual indication is usually supplied, and this takes the form of a small lamp placed in parallel with the main switch controlling the whole of the cooker elements, so that when the main switch is on, the lamp remains lighted, thus indicating that current is passing. This, by the way, will apply to all apparatus where the elements are not seen. Heat control of all this type of apparatus is carried out by dividing the heater element into halves and using a series-parallel method of switching.

A length of suitable cable connects the distribution box to the cooker control panel on the wall of the kitchen (in all cases the connections to the distribution point are the same for all points), and the other end of the twin cable is attached to the bottom end of the cooker main switch (Fig. 6). From the top end of the switch will be two sets of wiring; one pair to the batten lamp-holder and the other pair to the terminals on the cooker. Examination of the outside frame will reveal an earthing terminal, and to this a piece of cable has been attached and taken to earth. This is a most important point.

The Water-heater.—For explanatory purposes deal with one particular type of heater manufactured by one particular maker, the reason being that all immersion-type heaters vary somewhat, and all the heaters manufactured by this firm have the same connections, whatever the wattage.

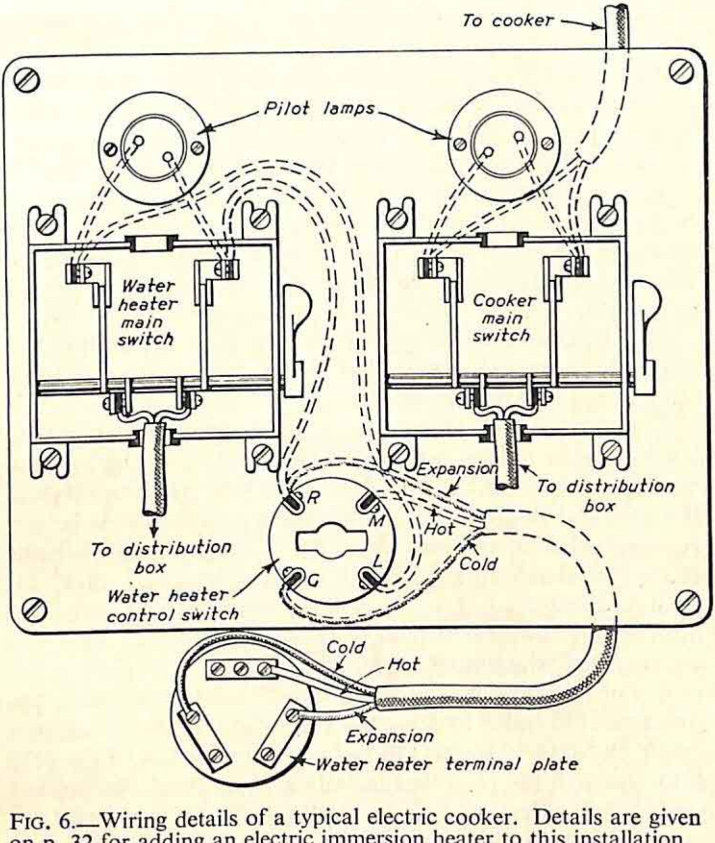


FIG. 6.—Wiring details of a typical electric cooker. Details are given on p. 32 for adding an electric immersion heater to this installation.

It is usual to use this kind of heater in conjunction with the existing hot-water installation, but a complete installation of electric heaters may be used, and the diagram (Fig. 7) applies to both complete and assisted systems. The assisted system is dealt with first, as this will be the same as the new hot-water installation, with the exception that a plumber must be called in to fit the piping.

As a rule the hot-water supply tank is fitted in the airing cupboard, either in the back bedroom or other convenient upstairs part of the house; before any fitting can be done it is necessary that the tank should be emptied. Most tanks will have a round plate on one side secured either by means of bolts or a clamp, and this plate must be removed to allow access to the inside of the tank. Next a hole $1\frac{3}{16}$ in. diameter will be needed in one side of the tank as near to the bottom as possible.

Should the tank be one of those that are without a manhole, a special flange for outside fitting can be purchased, and the hole is then cut to suit the flange.

Remove the locknut on the heater and push the end into the tank, but before pushing right home slide the locknut over the end again, ready for screwing into position. Before the lock-nut is drawn up, steam-tight packing must be put round the inside and outside joints of the tank, and for this red lead and asbestos string will make a very good joint. To refill and test the joints, turn on the main water supply and attach to a convenient cold tap a short length of hose, the other end of which must be attached to the nearest hot-water tap. Turn on both hot and cold taps, thus allowing the high-pressure cold water to drive out the air in the tank; if all is in order, the air and water will be heard rushing out of the cold tank through the pipe that usually supplies water to the hot tank. Do not attempt to do anything further until you are assured that the hot tank is full.

Looking at the projecting end of the heater, it will be seen that three terminals are fitted, and these are for varying the heat. The switch at the other end will also have corresponding terminals, and for the three-point connections triple cable must be used. The current for the heater will be

12 amps., therefore triple 7/0·044 will be used. The different cables will be marked in various colours, so that they cannot be confused when making connections at different ends of the circuit. In the drawing of connections for the water-heater the cables have been marked, but whatever the actual colours provided, like colours are connected to the points.

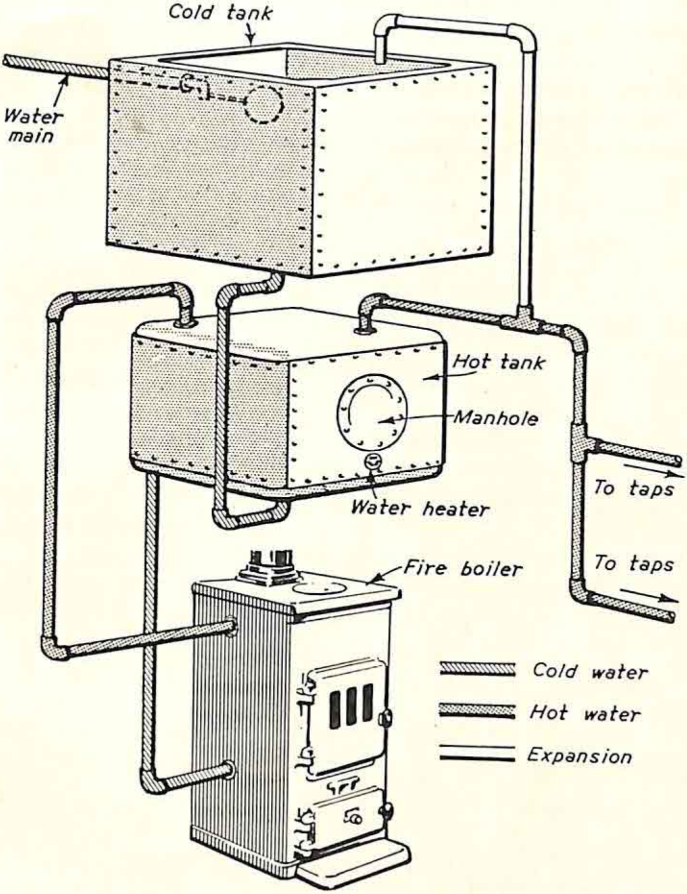


FIG. 7.—Diagram of the usual fire-heated hot-water system of the water-heater.

Connection from the distribution box to the main switch for the heater will be by twin cable, in exactly the same way as for the cooker, and the pilot lamp is also wired in exactly the same manner. The switch used for the heater control is of the non-reciprocating type, and it is usual, when more than one pilot lamp is in use, to arrange to have them of different colours, to prevent confusion over the two circuits.

When considering what size of heater to purchase, the capacity of the tank in gallons may be found in the following manner:

Rectangular tank—

$$\frac{\text{Height} \times \text{width} \times \text{depth (in inches)}}{276} = \text{gallons.}$$

Cylindrical tank—

$$\frac{\text{Dia.} \times \text{dia.} \times 0{\cdot}78 \times \text{depth (in inches)}}{276} = \text{gallons.}$$

V

ELECTRIC LIGHT AND POWER INSTALLATION

AN explanation has been given in a previous chapter, showing how, by applying Ohm's Law, calculations relating to voltage, current and resistance can be made. That information is now amplified.

Voltage is the pressure at which the power is supplied. It varies according to the town or district, but is approximately constant at a fixed value, which may be 100, 110, 230 or 240 volts for lighting purposes and 400, 415 or 460 volts for power supply. On the Control Board standard lighting system the pressure is 230 volts at 50 cycles per second. This will probably be the ultimate standard for the whole country.

The ampère is the standard measurement of the flow of current in a wire or cable. The term is more or less synonymous to the measurement of the flow of water through a pipe in gallons.

The ohm is the unit of measurement of resistance to flow of the current. It is similar to the frictional resistance to the flow of water through a pipe.

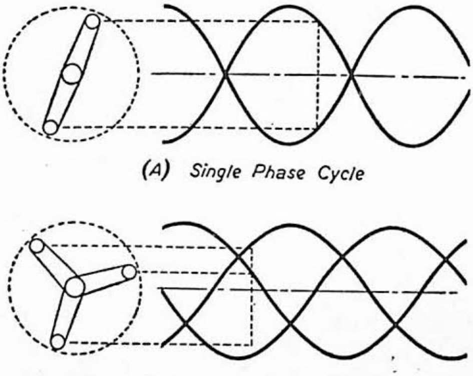
As an equation $\frac{\text{Voltage}}{\text{Current}} = \text{Resistance.}$

As an example, let us take a circuit with a potential of 230 volts passing a current of 10 amps.; from this it will be seen that the circuit has a resistance of $\frac{230}{10} = 23$ ohms.

By the ordinary rules of mathematics, $\frac{\text{Voltage}}{\text{Resistance}} = \text{Current}$ and Current × Resistance = Voltage. When given two of the factors, the third is easily deduced.

Electricity wires—they are usually called conductors—are almost invariably made of copper, because this metal has a low resistance and, therefore, high conductivity. Some conductors are made from stranded wires for purposes of flexibility (flex). Special nickel-chrome wire is used for heater elements.

Direct and Alternating Currents.—There are two electricity systems available, according to the local supply—viz., direct and alternating current. Direct current flows in one direction with a stable potential. In conventional terms it always flows from positive to negative. Some scientists assert that the current actually flows from negative to positive, but, be that as it may, it always flows in the same direction.


(A) Single Phase Cycle

(B) Three Phase Cycle

FIG. 8.—Wave forms of alternating current.

Alternating-current systems are rather more complicated and difficult to deal with; although alternating current has superseded direct current in most districts and will entirely replace it as the grid system develops. Alternating current flows in waves and, as the name implies, it alternates, or changes its direction of flow at periodic intervals. The standard frequency of the grid system is 50 cycles per second, i.e., the current changes its direction 50 times in one second. The shape of the wave is dependent on the generating dynamo, but it generally takes a form similar to that shown in Fig. 8*A*. If its shape is theoretically perfect it forms a pure sine wave—i.e., it conforms to a mathematical law and its complex values can be accurately calculated.

Referring to the diagram, Fig. 8*A*, it will be seen that the voltage (and current) have a continuous sequence, rising to a maximum value in one direction of flow in the circuit and then subsiding to zero. This is followed by an alternation, and the current in the circuit changes its direction, increases to a maximum and again returns to zero. The sequence is continuous so long as the current flows. The time taken to make a complete cycle is called a period, and the number of periods or cycles per second is known as the frequency.

Distribution Systems.—When a heavy current has to be generated to supply a large number of consumers at a comparatively low potential of 230 volts, the demand could be met only by laying down extra cables. To overcome this difficulty economically, the power is generated at a potential of 460 volts and distributed on a three-wire system: by this means only half the current is needed for the same power output. The third wire, connected to earth, is run from the power-station. Two power-mains have potentials, one 230 volts above and the other 230 volts below the potential of the earth, as shown diagrammatically in Fig. 9. An equal number of consumers are connected between the positive and negative power mains and the neutral, or earthed lead, to obtain a balance as near as possible.

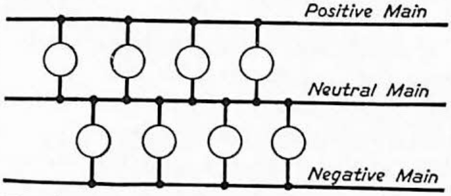


FIG. 9.—Diagram of three-wire distribution.

The two mains currents flow in opposite directions in the earth wire, so that the current it actually carries is only the difference between currents carried by the positive and negative main cables; in consequence, the neutral wire need be of only small capacity.

Electric systems with three wires were first used for direct current, when two voltages are available—i.e., 230 volts or voltage according to the supply, between either outer lead and earth, or 460 volts between two "outers", or positive and negative mains. With simple alternating current the electricity is driven to and fro through the two main leads from the power-station. This system is known as "single phase", to distinguish it from the "three-phase" system now in general use.

The difference between single-phase and three-phase systems is equivalent to the difference between a two-crank and a three-crank engine. The former has its cranks 180 degrees apart, giving two dead points per revolution (see Fig. 8*A*). In the same way the alternator raises the potential of each lead in turn, so that when the potential of one is up, that of the other is down by an equal amount, and twice in every alternation the potential difference between the leads is at zero. Using the same simile, three cranks equally spaced would be at 120 deg. apart, giving a more even turning movement. This corresponds to rise and fall of the alternating potentials of a three-phase current supply; in the three mains they rise and fall in regular succession (see Fig. 8*B*).

For lighting and heating, connections are made between different pairs so as to distribute the power equally among the three wires. Electric motors can be connected between a pair of wires as for a single-phase supply, but the three-phase supply is specially suited to drive motors which have the windings connected to the three power-mains.

Conductors.—The conductors are the most important part of any electrical installation. They must be fully protected against mechanical damage to the installation, and from deterioration that may be caused by dampness or, in some positions, by chemical fumes. Fire is the greatest danger, and this is generally caused by a failure of the insulation allowing two wires to make contact or a short circuit to earth.

Local electricity authorities are not favourably disposed towards exposed V.I.R. (vulcanised india-rubber) cables, even when they are apparently well insulated, and some insurance concerns will not grant a fire policy for premises with installations of this type. Practically all modern lighting and power installations now employ steel conduit. Lead-covered cables are equally satisfactory for exposed wiring, but where it is buried in wall plaster there is always a danger of nails being driven through it.

Steel Conduits.—There are three types of steel conduit—viz., closed joint, brazed joint and solid drawn.

Closed-joint tubing is made from rolled metal, and has a more or less open seam through which dampness can penetrate. In dry positions it gives satisfactory protection to the cables, if properly fitted. Brazed-joint tubing is similar to the closed joint, except that the seam is closed by brazing. It provides greater protection for the cables, but as the joints are of the slip-in type they are not water-tight. The special fittings are secured by pin grip or by grip joints, as shown in Fig. 10.

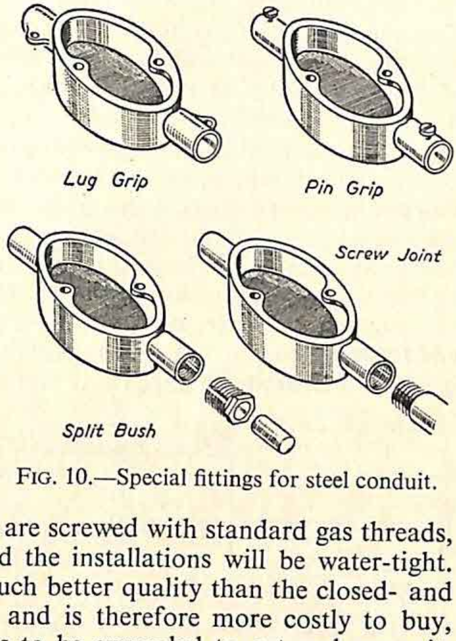
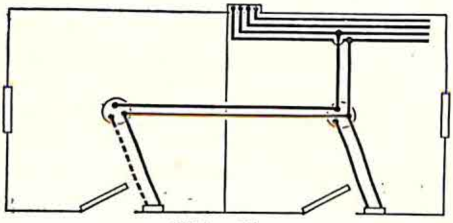


Fig. 10.—Special fittings for steel conduit.

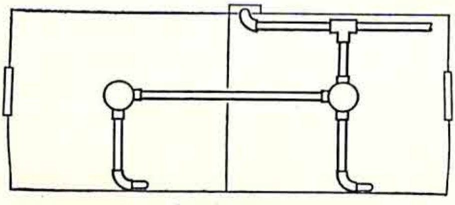
Solid-drawn tubing is used on all first-class work. It is similar to gas piping, but of lighter gauge and smoother internal finish. All the joints are screwed with standard gas threads, and if properly fitted the installations will be water-tight. This tubing is of much better quality than the closed- and brazed-joint tubing, and is therefore more costly to buy, and more labour has to be expended to cut and screw it. For small installations the extra first cost is not very much greater and the extra expense is well worth while. The initial outlay can be reduced by using closed-joint tubing in perfectly dry positions and screwed tubing in cellars, bathrooms and kitchens, where dampness may cause trouble.

Steel conduit sizes are graded according to the outside diameter of the tube, not the bore, as in the case of gas and steam pipes. Solid drawn tubing conforms to pipe-size threads, so that standard gas-screw dies can be used. To ensure electrical continuity it is essential to clean off the enamel at the joints from both the tubing and the inside of the fittings. Care must always be taken to ensure that the tubing goes well inside the fitting, so that it is securely gripped without damage to the cables.

Planning the Installation.—Every installation should be properly planned before work is started. It is best to obtain a plan of the house from the builder or architect showing the positions of windows and doors, and indicating the materials of which the internal walls are constructed. On the plan mark the proposed positions of lamps, switches, plugs and other fittings. The layout of the wiring can then be drawn in, showing the positions of the fuse-box, junction boxes or looping-in points, if these are more convenient. In some cases it may be preferable to loop-in at a three-point ceiling rose or at the switch. The positions of the distribution board and fuse-boxes are most important. They should be in an easily accessible place, both for running in the main cable and for switching on and off, as may be necessary. A typical point plan is shown in Fig. 11.



Wiring Plan



Conduit Plan

FIG. 11.—A typical point plan.

After making a careful study of the plan, the live-wire runs can be marked in with red ink and the neutral wires with black ink. When this has been completed, the sizes of the cables can be indicated, according to the current they will carry. The sizes of the tube runs can also be arranged in accordance with the number and size of wires they will

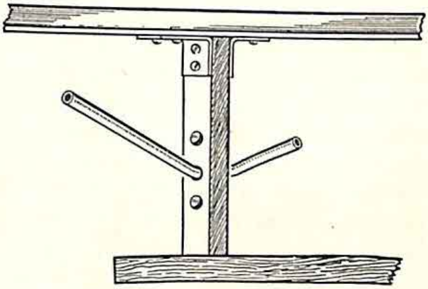


FIG. 12.—A bending block.

carry. These items will be dealt with in greater detail later. When fixing the size of the tubing it is always advisable to leave room for one or two more wires that may be required for future extension. A close estimate of the number and type of fittings should be made so that the whole installation can be purchased without waste of material.

Bending the Tubes.—For solid-drawn tubing it will be necessary to have a pipe vice and a set of stocks and gas dies from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. For any type of tubing it is a great advantage to have a bending machine. A good substitute is a piece of strong wood about 4 in. by 2 in. in section. Through this holes are drilled to take $\frac{1}{2}$-in., $\frac{5}{8}$-in. and $\frac{3}{4}$-in. tubing, as shown in Fig. 12. The edges of the holes should have a good radius, or the tubing will be kinked and spoiled. The tubing is set by putting it through the appropriate hole and gradually bending until the desired angle is obtained. The tube should be moved backwards and forwards during the process and the radius made as great as the position of the angle permits. Sharp bends are difficult to form ; in fact, should not be attempted. It is much better to cut the tube and use a standard elbow if a sharp right-angle bend is required. Closed-joint tubing should be bent with the seam on the inside or outside of the radius. Very large tubing for main cables is usually filled with lead or dry sand before bending.

Earthing Connections and Earth-leakage Trips.—In most houses the metallic cable sheathing or conduit, the earthing sockets of three-pin socket-outlets, and other exposed metalwork requiring to be earthed is connected to the rising main from the water supply system by means of a tinned-copper conductor of not less than 7/0·029. This arrangement is generally satisfactory where the water supply is from an urban system of underground metal pipes having metal-to-metal joints. If an earthing terminal is provided on the metal sheath (and armour) of the incoming electric supply cable this could then be used as the earthing point to which the exposed metal parts are to be bonded.

Where such alternatives are not available the consumer may have to provide his own earth electrode, as the connection to the general mass of earth is called. For most purposes a galvanized iron plate about 30 in. square which is buried vertically about three feet deep in the ground will suffice, if buried in a position where the ground is reasonably moist. It should be pointed out that, for safety, the impedance of the earthing system should be tested by a competent electrician to ensure that this is low enough to allow the passage of sufficient current to melt the protective fuses in the event of an earth fault, or failure of the insulation between an electrical conductor and earth.

Leakage Trips.—In some places it is, however, difficult to provide an earth electrode of sufficiently low impedance to protect circuits of high current rating which are protected by fuses of high current value. Protection against earth-fault currents may then be provided by means of a voltage-operated earth-leakage trip. With this system the metal parts requiring to be earthed are bonded together by means of a conductor of not less than 7/0·029 and are connected to one side of a leakage trip coil, the other side of which is connected to an earth electrode. This protective system is normally effective even when used with an earth electrode of fairly high impedance, and the earth electrode may comprise a piece of iron or steel tube about 1¼ inches in diameter which is driven about 4 ft. into the ground.

The lead from the trip coil to the earth electrode should be insulated and installed in a position well away from the point where any services, such as water or gas pipes, emerge from the ground or lie in the ground. Under no circumstances should any part of the exposed metal work of the electric system be allowed to come into contact with a gas pipe.

VI

LAY-OUTS AND WIRING METHODS

It is the general practice to "run" steel conduit for electricity installations before the builder lays the flooring or plasters the walls and ceiling. In the trade this is called "carcass" wiring. The work must, of course, be done in co-operation with the contractor, or the whole building operation may be disorganised.

For all good-class work the conduit installation is completed before the wiring is run. It is advisable to give the house time to dry out, and to wire to the fittings just before painting and internal decorations are started. Wires should not be drawn in until all nailing is finished and the house is reasonably dry.

Tubing should not be started until the roof is on the house and the dwarf walls and joists of the lower floors are in position. Usually the tubing on the upper floor is run first, and the work continued downwards, but the wiring of the upper floor is done last. By that time the middle floors will have been laid and can be used to support ladders and other necessary appliances.

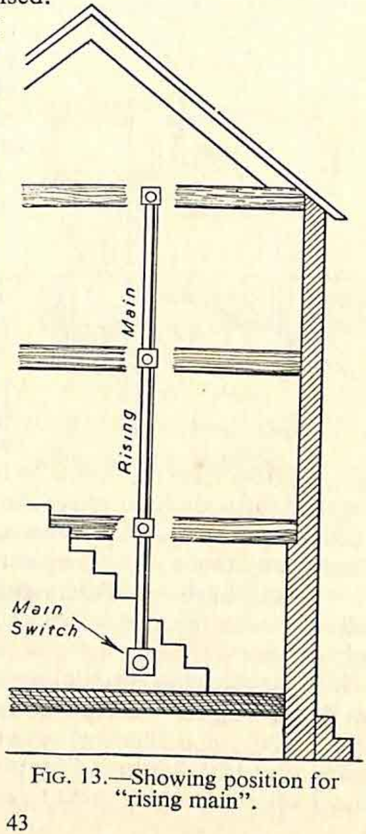


FIG. 13.—Showing position for "rising main".

Locating Lighting Points.—Before starting any work it is most essential to study the plans, so that the exact locations of the lighting points and switches can be fixed by accurate measurement. One of the most important items is the choice of the position for the "rising main" (Fig. 13). This conduit carries the main feeding wires from the meter board to each floor level. Owing to the fact that the meter board is usually fixed under the stairs, the run to the first floor is often the most awkward. All such tubing must be given ample bends and a junction box provided on the landing in a convenient position to draw in the wires. Alternatively, intermediate inspection boxes must be fitted at awkward angles and bends.

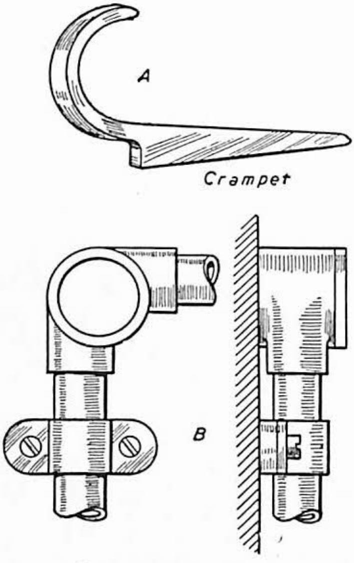
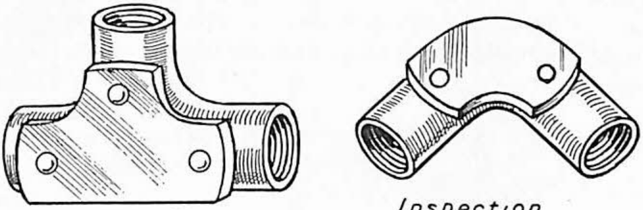


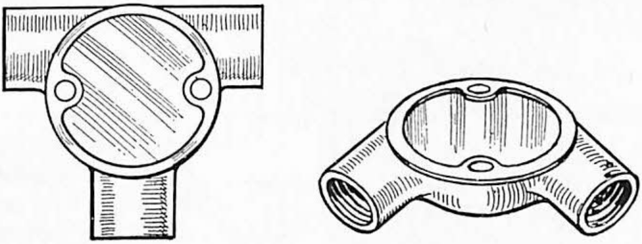
FIG. 14.—Methods of fixing tubing.

Wiring is drawn into the tubing by means of a wireman's "snake", which consists of a coil of spring steel wire or tape, with a brass ball at one end and a loop at the other. It is advisable to test all tubing by passing the tape through it to make sure that it will go round the bends and there are no obstructions in the conduit. To remedy any faults after the plastering has been done would be a costly business. All inspection covers must be carefully replaced to exclude dirt and damp while the plastering is being done.

Inferior electrical installation work can be as dangerous as leaking gas pipes. Unfortunately much wiring work is cheap and shoddy, and this causes considerable trouble in a few years after installation. Cheap slip-in tubing is often used under the roof, which, next to a cellar, is the dampest place in the house. In many instances it is laid loosely across the joists with no clamps. If the space under the roof is used for storing boxes, the least movement of the conduit pulls it from the fittings. The sharp edges of the tubes cut the insulation of the wires and cause short circuits. Most fires originated by fusing are due to poor electrical work of this kind.



Inspection Tee *Inspection Elbow*



Circular Type *Circular Type*

FIG. 15.—Inspection elbows and tee-pieces.

All tubing should be cut to exact lengths so that it can be gripped or screwed securely in the fitting to which it runs; but it must not project too far into the joint, or the sharp edges will cut the wires when they are being drawn through. The most satisfactory results are obtained by securing the fittings temporarily in position and then measuring the distance between them; by adopting this method the tubing can be marked off and cut exactly to the required length. Before final fixing, the ends of the tubing should be carefully filed and rounded in the bore.

Saddle Clamps.—All tubing should be secured and supported at intervals of not more than 3 feet, by saddle clamps to joists and other woodwork and by crampets to brick walls, as shown in Fig. 14*A*. Spacing saddles are used to secure tubing, where it runs into a fitting, to bring it into alignment with the threaded inlet, as shown at Fig. 14*B*. There are, of course, numerous kinds of fitting for various purposes, some of which were shown in the previous chapter: other fittings are shown in Fig. 15. Fittings with inspection plates simplify wiring drawing and they should be used at all angle turns in preference to plain elbows. When a bent tube is used to turn a corner it should be as generous as possible, and never of less than 4 inches radius. All runs must be planned so that the draw wire can be passed from point to point.

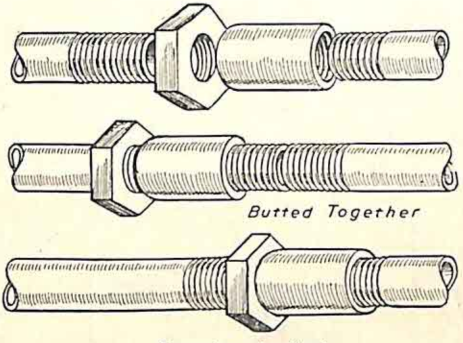


FIG. 16.—Three positions of a running coupler.

Running Couplers.—Long lengths of tubing for straight runs, or tubing in such a position that it cannot be turned, may be joined with a running coupler as shown in Fig. 16. One conduit end is screwed to a length sufficient to take a coupler and locknut. The two conduit ends are then butted together and the coupler is run back on to the other length of tubing; the locknut is screwed tightly against the end of the coupler to prevent it turning.

Where tubing is run into junction boxes or other fittings that are not threaded, either of two methods can be used to secure it in position. By the first method, a sleeve coupler is screwed on to the end of the tubing, and a screwed bush, passed through the hole in the junction box and screwed into the coupler, as shown in Fig. 17*A*. The rounded end of the bush prevents the wires from chafing. A second and simpler method is to run the tubing through the hole in the box and secure it with two locknuts, one on the outside and the other on the inside, see Fig. 17*B*.

It is sometimes necessary to join two runs of tubing of different sizes, or to join up to a junction box that has a larger opening than the tube size. In both cases a reducing nipple is used, which is threaded externally to fit the larger screw thread, and internally to take the smaller, as shown in Fig. 17*C*.

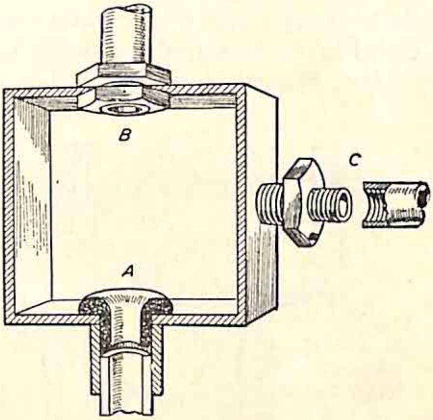


FIG. 17. Section of a junction box showing connections for tubing.

Carcass Wiring.—Simplicity should be the keynote of all carcass wiring, and the runs planned with as few junction boxes as possible. This method is not only economical in the cost of fittings, but it also reduces the number of traps to be made. Bends are easy to form (but they must be generous) and are preferable to a multiplicity of connections. They should be so placed that the wires can be drawn into and out of the tubing with a minimum of structural disturbances.

Junction boxes should be arranged so that they are in the least conspicuous positions; where likely to be unsightly, the face of the box should not protrude above the plaster surface of the wall. In such cases the conduit must be sunk into the brickwork far enough to make this possible. The position of the groove is first marked on the brickwork with a carpenter's pencil, and also the position of the recess for the junction, switch box, or wooden fixing block. The chase, or channel, is neatly cut with a special tool known as an electrician's chaser, or with a bricklayer's bolster. Both tools resemble very wide cold chisels, and they must be really sharp. A small chaser is just the width of a brick—i.e., 3 in.—and is used to line out the positions marked; the pieces of brick must be carefully removed. Extreme precaution must be taken not to dislodge the bricks.

Conduit is usually sunk in the brickwork to a depth of about half its diameter, which should bring the face of the box level with the finished plaster surface. The box is secured in position and the conduit run into it. It is advisable to cement round a large box to keep it square with the wall. Where junction boxes are fitted to joists, before the floorboards are laid, arrangements should be made with the carpenter to make traps that can be easily lifted to facilitate wiring. All runs should be planned so that the cables may be passed from the junction box to outlet points without the aid of a draw wire. It should be necessary to use a draw wire only when there are several bends in a run. All conduit runs under the floorboards must be kept close to the walls so that the joists are not notched near their centres, which would weaken them where the greatest strain has to be taken.

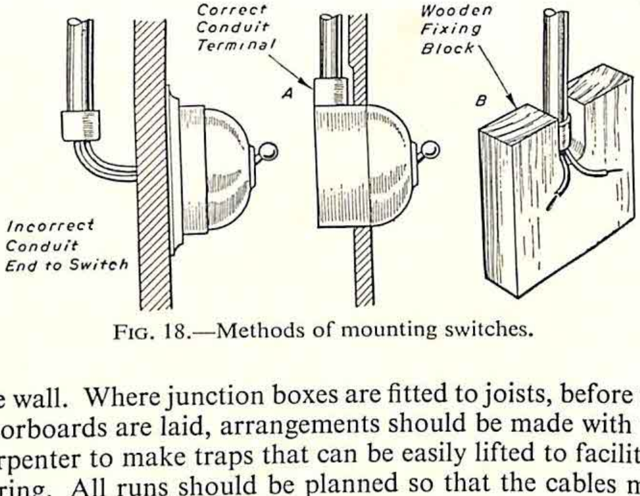


FIG. 18.—Methods of mounting switches.

Wooden Switch Blocks.—The use of wooden blocks for fixing switches and ceiling roses is fairly common, but is neither good practice nor a really safe method. A more satisfactory way is to use ironclad fittings, as shown in Fig. 18*A*. These are screwed or otherwise secured to the end of the tubing and ultimately set in the plaster. By this method the switch does not need a wooden surface mounting block, and the fitting is therefore much neater because it does not protrude above the wall face. When adopting the former method a wooden block, about 4 in. square and 1 in. thick, is nailed to the brickwork, and the tubing terminated with a vulcanite or rubber bush to protect the wires, as shown in Fig. 18*B*.

Light-points.—Several different methods can be adopted for light-points. A ceiling-point can terminate in an iron flush-box, which has two tapped holes for fixing the ceiling rose or pendant. The box must be securely anchored on each side with battens to keep it in place, as shown in Fig. 19*A*. If the point ends with a bushed tube it must be terminated at the under-surface of the ceiling, Fig. 19*B*. Where the point is dropped from the back of a junction box, blocks must be provided to carry the ceiling rose or pendant. If the point is run from a bend, the tubing can end near a joist, and this may be used as a fixing point, Fig. 19*C*.

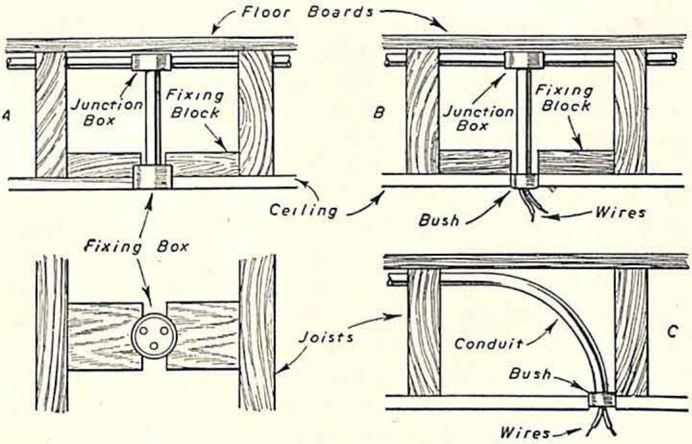


FIG. 19.—Various methods of anchoring light-points to a ceiling.

VII

HOUSE CIRCUITS

THE main cables of all installations are led to a main distribution board, and from there the current is distributed to the various localised centres which may be on different floor-levels.

Local distribution boards are placed as near as possible to the centre of the area they serve. From the local boards conductors radiate to various branch circuits. Each of these circuits will feed a number of lighting and/or power-points. The number of points is usually limited to not more than ten on one fuse. In case of a short circuit blowing a fuse the least number of points put out of action the better; it is also easier to locate the source of trouble.

House Circuits.—Ordinary private house installations usually have only one distribution board, or box, with fuses on both poles of each circuit. The circuit feeds all the points on one floor only, so that it is quickly known which fuses have blown without having to withdraw all of them for inspection. Incidentally, the fuse-box should have a diagram inside the lid, showing the position of the fuses for each floor. Unfortunately, most small installations have only one switch serving the distribution board. A first-class installation will have a switch for each circuit. A fuse should not be changed without switching off, for it is not safe to tamper with a live circuit.

Capacity of Cables.—All electric cables develop heat when a current is passing through them. As the temperature rises the resistance of the wire to the passage of the current becomes greater, and this causes a loss of voltage.

The safe current-carrying capacity of a cable, in ampères, is proportional to its cross-section. It must be of such a size that the rise of temperature is not appreciable when carrying a maximum load. In lighting circuits a very small fall in potential makes a considerable difference to the illuminating power of the lamps.

On long main feeders the cross-section area is calculated to give a minimum voltage drop. It is the general practice to install cables of little greater capacity than is necessary to carry the possible maximum load. Too liberal an allowance in this respect will add very considerably to the cost of cables and other materials. There are also other important factors which require consideration.

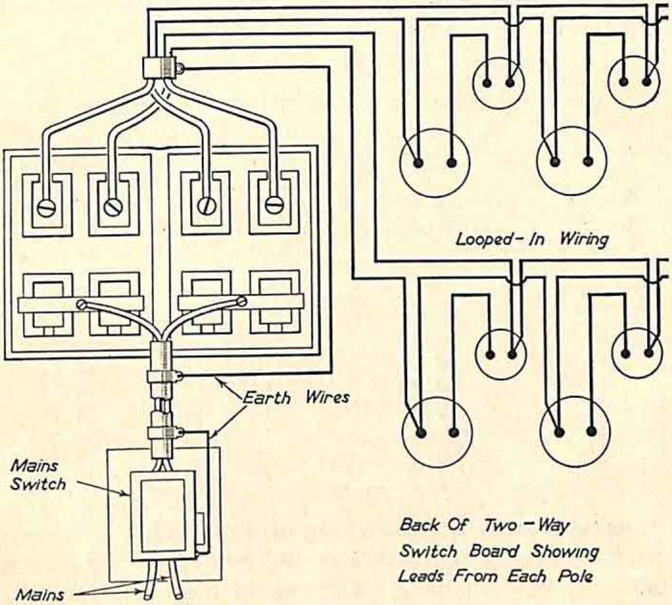


FIG. 20.—Diagram of looped-in wiring system.

Standard Loading Capacity.—Standard maximum loading has been fixed by the rules of the Institution of Electrical Engineers. The amount of current that can safely be carried by a cable depends on the cross-section area of the wires, and the rise of temperature within safe limits. Heat that is developed in a cable is dissipated to the surrounding atmosphere through the insulating material. Much, therefore, will depend on the composition and thickness of the insulation, and, in turn, the thickness of the insulation depends on the voltage of the system.

A metal conductor (copper in most cables) of small cross-section area has proportionately greater surface area than a thick conductor. It has, therefore, a proportionately superior heat dissipating area. Within certain limits, a thin conductor can safely carry a higher current density than one of greater cross-section.

The following table gives a range of suitable cables to carry from 5 to 37 amps.

CURRENT-CARRYING CAPACITIES OF CONDUCTORS

No. of Strands.	Diameter of Wire (in.).	Carrying Capacity in Ampères I.E.E. Rules.	Approx. Length in Feet (lead and return) for 1 Volt Drop by I.E.E. Rules.
1	0·044	5	36
3	0·029	5	47
3	0·036	10	35
7	0·029	15	34
7	0·036	24	33
7	0·044	31	39
7	0·052	37	45

Conduit Sizes.—Before wiring an installation it is most important to determine the size and number of wires to be run. This will depend on the system of wiring adopted, which will be dealt with later. The number of cables to be run determines the size of the conduit. If the correct size of tubing is used no difficulty will be experienced in drawing in the wires and easing them from one bend to another, or from a tee-piece or elbow to the tube ends.

Wiring is always a two-man job; one is needed on the draw wire while the other feeds in and eases the wires around bends to prevent damage to the insulation. Should the cables be too tight a fit in the tubing the insulation may be damaged and the wires stretched or even broken. Powdered french chalk, sprinkled on the insulation, may be used as a lubricant to assist when drawing in. Anything of the nature of grease or oil must not be used in any circumstances; the insulation would be ruined.

The following conduit wiring table may be taken as a general guide for tube sizes.

CONDUIT WIRING TABLE

Giving approximate number of cables that tubes can contain.

Cable Size.	Light Gauge. Size of Tube.				Heavy Gauge. Size of Tube.			
	½ in.	⅝ in.	¾ in.	1 in.	½ in.	⅝ in.	¾ in.	1 in.
1/0·044	2	4	6	10	2	3	5	8
3/0·029	1	4	5	9	1	3	4	8
3/0·036	1	3	4	8	—	2	4	8
7/0·029	—	2	3	7	—	1	3	5
7/0·036	—	2	3	6	—	1	2	5
7/0·044	—	1	2	4	—	—	—	4
7/0·064	—	1	1	2	—	—	—	2

Circuit Wiring.—The wiring from the circuit distribution boards is much smaller than that used for the main cables. As a general rule lighting circuits are divided up so that each carries a maximum load of about 3 amps.; the wiring is actually calculated to carry 5 amps. There is an alternative choice of two types of cable, viz., single-strand 0·044 gauge, or three-strand 0·029 gauge, known in the trade as 1/0·044 and 3/0·029 respectively. Stranded wires, being more flexible, are preferable to the single-wire type.

In good modern wiring work the use of jointed wire is bad practice, and in no circumstances should a jointed wire be drawn into a tube. Where a joint is unavoidable, for any particular reason, it is made in a special joint box or a junction box. Unsoldered, or dry joints, are barred at all times. No matter how carefully they may be made, corrosion is sure to develop in time; this will set up a high resistance that will generate heat, which may cause fire. There are occasions when a jointed wire is unavoidable, but it must always be soldered, and well insulated with a rubber sleeve and insulating tape.

Cut-outs and Fuses.—Every electric circuit is protected by a cut-out device to prevent damage to the wiring by overheating if a sudden overloading or a short circuit occurs; it also protects the lamps, motors and instruments in the circuit. At the power-station the mains are protected by automatic cut-out devices that break the circuit by dropping out the main switches. Similar devices are used for high-power motors. Ordinary house circuits are protected by main fuses fitted between the main switch and the distribution board, and each of the auxiliary circuits has a pair of fuses.

House fuse-boards are usually installed in a cupboard under the stairs, or in an inconvenient position in a pantry. It is very bad practice to place a fuse-board high up over a door where fuse renewal is difficult in an emergency. At the same time, the fuse-board must be kept out of reach of children, or placed where it is not likely to attract attention as a possible plaything. Where this danger exists an iron-clad fuse-box is safest, with a lid secured by screws, or a safety device which prevents the lid from being opened until the switch is off.

The fusible wire cut-out is, of course, simplest and cheapest. It is a well-known device consisting of a detachable porcelain hand-grip fuse-holder with two slip-in terminals on the base of the fuse-holder. To the terminals of the base are connected the incoming main cable and the outgoing circuit wire, respectively. Between the two slip-in terminals of the fuse-holder is a wire of copper, tin or lead of a thickness sufficient to carry an electric current of predetermined value.

Safety Fuse-holders.—Fuse-holders of the safety type are those with a tube or a channel through which the fuse-wire passes from one terminal to the other. Whether for quickness or ease, the fuse-wire must not be made to by-pass the proper course. The tubular type serves a double purpose; when a fuse blows the molten metal is retained in the enclosure and prevented from causing damage or fire; and the violence of the rupture induces heated air to rush out of the tube and break the arc as the circuit is opened.

All fuses are fitted between the switches and the lighting and power circuits, so that the current can be switched off before a fuse is renewed. A fuse acts as the weakest link in the chain, which will break before an overload can do damage. Generally a 5-amp. fuse-wire is used. Circuits carrying variable loads, such as those that feed electric motors, which normally take a heavy starting current, have fuses that blow at as much as 100 per cent. above the rated current intake of the motor.

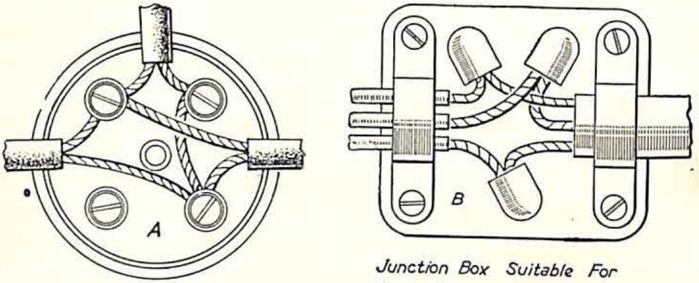
Looping-in Wiring System.—Most, in fact it might be said all, modern lighting circuits are wired on the "looping-in" system. This method has the advantage of being easy to run without having to make a multiplicity of joint boxes. Wires of two different colours are used to facilitate recognition at the connecting ends. The red wires are carried to the switches and the black to the lamps. Red, or switch wires are connected to the live side of the circuit.

Referring to Fig. 20, it will be noticed that the feed-wire is taken to the live side of the first switch and then looped out and carried to the live side of the next switch and so on in unbroken succession. The wires are of necessity cut at the switch, and the ends twisted together, but the joint is a safe mechanical one secured by the switch terminal screw. Provided the screws are tight there is little fear of corrosion. From the other terminal of the switch another red wire is taken to one of the lamp-fitting terminals.

The black wire from distribution board is carried to the first lamp fitting and from there looped out and taken to the next lamp fitting, in exactly the same way as the switch wires are run. Each lamp terminal acts as a mechanical joint fitting which is electrically sound, and is in a safe and convenient position within the fitting itself.

The great advantage of the "looping-in" system is the absence of intermittent joints. When it is necessary to test out an installation, or to trace a fault in the wiring, the positions of all the joints are known. It is necessary only to open up or remove a fitting to get at the bare end of a lead and connect a testing instrument.

Junction Boxes.—Looping-in is not always so simple as it may appear from the foregoing description; runs are not ideally straight, nor devoid of complications, and it is frequently necessary to use junction boxes, two examples of which are shown in Fig. 21. The junction box "A" has a special type of terminal which makes a sound mechanical joint. The box itself, being made of metal, provides for the continuity of the earthing system of the tubing. Box "B" is suitable for lead-covered cable, being provided with earthing clips that grip the metal sheath. The base of the box in this case is also of metal. Junction boxes of plastic material do not provide continuity and when these are used the outer sheaths of the cables are connected by a bare copper wire, preferably run round the outside of the fitting.



Junction Box Suitable For Lead Covered Cable

FIG. 21.—Two types of junction box.

On small installations a considerable amount of tubing and cable can sometimes be saved if the main leads are taken to a centrally situated junction box and from there the looping runs carried to the various switches and light-points. Various switching systems call for additional wires or a different arrangement of the looped-in wires.

VIII

SWITCHES AND CONTROL POINTS

CONVENIENCE and ease of control are the chief features of electric lighting that gave this form of illumination precedence over every other. When planning an installation, full use must be made of these advantages. All switches and control points should be placed where they are easily accessible when a room door is opened. It should never be necessary to search in the dark for a switch. Where a room has more than one door, a switch controlling the light is usually fitted at each door, these being interconnected, but independent in action. Intermediate switches are also fitted in long passages with doors leading off to various rooms, and on staircases and landings. A convenient height for a switch is 3 ft. 6 in.

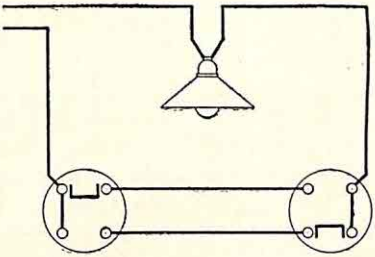


FIG. 22.—Two-way-switch circuit.

Multiple-point Switching. — Special switches with these three terminals are used for two-way switching. These are diagrammatically illustrated in Fig. 22, with the method of wiring. It will be seen that the live wire is connected to the common terminal of one switch, but the common terminal of the other is connected to the lamp feed-wire. The two switches are connected by intermediate wires. With this arrangement the light can be controlled by either switch, irrespective of the position of the other.

In the same way a light can be controlled from any number of points by using intermediate switches wired as shown in Fig. 23. In this case the two outer switches are of the three-terminal type, but the intermediate switches are of the four-terminal type. These are of slightly different design and are provided with reversing connections which are wired as shown.

Where two-way or multiple-point switching is installed on staircases and landings, both the switch and light-points should be taken from one power circuit, either that of the ground floor, or an upstairs circuit. For the sake of economy there is often a temptation to use the power circuits of two different floors; but if a short-circuit occurs, the lighting of two floors will be out of action, instead of one.

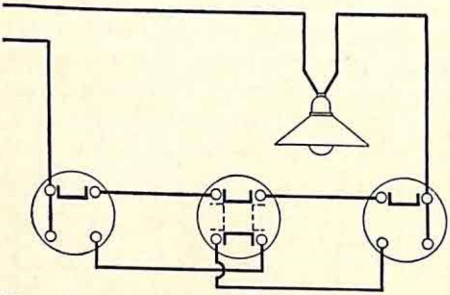


FIG. 23.—Two-way and intermediate circuit.

A similar method of wiring is adopted for bedroom light circuits to facilitate control either from the door or by a person lying in bed. For the latter purpose a ceiling pull-switch or pear-type switch should be used, Bed reading-lamps need have only a single control.

Converting a Light Control.—A bed-light controlled by one switch can easily be converted to two-way switching at very little expense. All that is required are two wooden blocks, two two-way switches and a length of triple cable to run from the original switch position to the new additional switch.

The old one-way switch and wood blocks are removed and discarded. The two new blocks are drilled for the two-way switches; these, of course, will have three holes in each to coincide with the three switch terminals. If the cable is run on the surface of the wall, a groove will be cut in the back edges of the blocks to allow for egress of the triple cable.

On removing the old switch, it will be seen that the two wires at the back are in a horizontal position. These must be altered to occupy a vertical position—i.e., one above the other—instead of side by side. One cable terminal will probably consist of two wires twisted together; the two wires must not be parted.

The triple cable is first fixed, or sunk, into position, and the ends of its wires trimmed to connect to the switches, and the wood blocks screwed in position.

It will be seen that the three wires of the triple cable have insulated cases or cotton coverings of different colours—red, black and white, respectively. Place the red lead in the position previously occupied by the wire now in the vertical position (which was probably red). One end of the red lead of the triple cable is connected to the common terminal of the new two-way switch, and its other end to the common terminal of the additional switch. The other leads, black and white, are connected, with the original switch wires, to the remaining switch terminals; and their other ends to the corresponding terminals of the additional switch, as shown in Fig. 24.

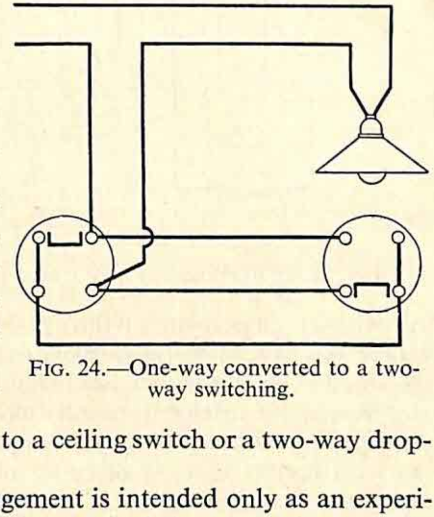


FIG. 24.—One-way converted to a two-way switching.

Instead of a wall switch the wiring can be run, and connected to a ceiling switch or a two-way drop-switch over the bed.

The foregoing arrangement is intended only as an experiment. If the point is being rewired the connections will be made as for an ordinary two-way circuit, as shown in Fig. 22.

Wiring an Electrolier.—Sometimes it is necessary and desirable to fit an electrolier with a multiple-light control which permits independent switching of one or more lights. Assuming that an electrolier has three lights controlled by two switches, the feed-wires will be run to the switches and lamp-holders as in an ordinary circuit. The wiring is shown diagrammatically in Fig. 25. In this example the top switch controls one light, while the bottom switch controls the other two. It will be seen that the live switch is looped from one switch to the other, but each switch has a separate lead to the light fitting. Special three-terminal ceiling roses are obtainable for this method of wiring, or the wires can be jointed and soldered together and a ceiling plate used. In the latter case the insulation must be soundly finished.

An electrolier can be converted to multiple control from the original single-switch lighting. In most instances wires will be required, and, if possible, these should be drawn into the conduit, and two switches installed in the normal way. Unfortunately, tubing is usually skimped in size and no provision is made for wiring developments. When remedying such defects there is often an objection to pulling up flooring or making structural disturbances which add considerably to installation costs.

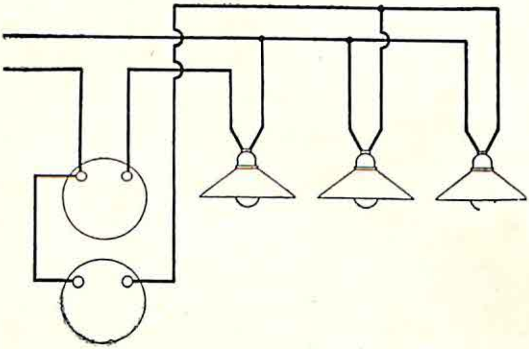


FIG. 25.—Circuit with two switches controlling three lights.

The simplest and quickest way of overcoming the difficulty is to fit a suspension switch from the ceiling rose and to re-wire the fitting as shown diagrammatically in Fig. 26. It will be seen that the wall switch still controls one light, but the circuit of the other two lights is intercepted by a suspension switch. The live side of this switch is fed from the wall-switch lead running to the single light, but the other side of the switch is connected to the return lead through the other two lamps, which are, of course, wired in parallel. By this method the suspension switch can be so fitted that it looks like a part of the electrolier. If preferred, a ceiling pull-switch can be used.

Metal-sheath Cables.—Lead-covered cable is largely used for surface work, but there is nothing to preclude its being sunk in the plaster of dry internal walls. Even in wet positions, if the metallic sheath is sound, it is perfectly safe. There is a possibility of corrosion, caused by electrolytic action, in a fume-laden atmosphere, or where chemicals are used.

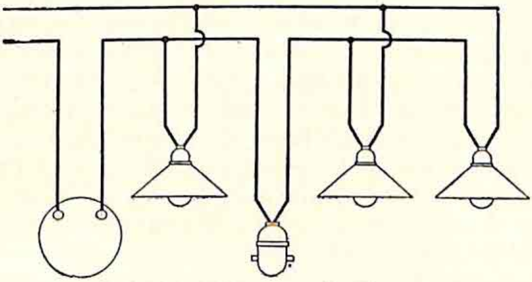


FIG. 26.—Three-light electrolier controlled by wall and suspension switches.

There are several types of cable made by different well-known manufacturers, and each has a specific system of installation. All fittings and accessories down to the smallest detail should be those supplied by the maker of the cable being installed; no difficulty will then be experienced in matching the various parts.

Some makes of cable have an earthing wire incorporated within the metal sheath, and in contact with it. With this type, suitable provision is made on the junction boxes, switches, and other fittings for connecting the earthing wire. This usually takes the form of a small pin to which the wire is secured. Where necessary for continuity purposes, the earth wires are joined together by a small thimble or a sleeve connector of light aluminium alloy. Another widely used system is earthed by bonding bars which clamp the metal sheathing where it enters the junction boxes and at other fittings with flat screw-down contact bars.

Lead-covered cable is supplied by all makers coiled on a wooden drum, from which it should not be removed until actually run into position and secured by metal clips. Cable of this type is somewhat delicate to handle; it is liable to "kink" if sharply bent or twisted, and the sheath is very difficult to straighten. The fact of being kinked is not functionally detrimental, but it looks ugly and unworkmanlike.

The run is first measured and marked out in as straight a line as possible, and the metal clips secured in position by suitable nails, or screws with small heads. The number of clips used depends on the size and weight of the cable, but economy in this respect is false. On an average, the spacing should not exceed 8 or 9 in. on horizontal runs, or 12 in. on vertical runs. Metal-sheathed cable, being comparatively heavy, is liable to sag and may pull away the clips.

To run this type of cable is a four-handed job; one man is needed to support the weight, while the other manipulates the clips. The drum can be rigged up on a tripod so that it revolves freely on a spindle. A particularly long run can be temporarily supported in rope slings in line with the clips. By this method its length can be gauged before the cable is clipped in position.

Some straightening and bedding will probably be required. This can be done with a block of soft wood and a hammer or, preferably, a wooden mallet. If a hammer is directly applied to the metal sheath it will cause bruising and spoil the appearance of the work.

Concealed wiring of this type may be run from point to point by the shortest route, but surface wiring must be run in a rectangular form so that it conforms to the general lines of the room or building. This frequently necessitates running by devious routes that require considerably more cable and makes looping-in complicated and cumbersome. To some extent this difficulty may be overcome by using junction boxes of the type shown in Fig. 21.

With the metal-sheathed cable system most of the wiring is on the surface, and it is therefore more convenient and less costly to cut the wires and use junction boxes instead of looping by circuitous routes. Metal-covered cables must be bonded to provide a continuous earthed circuit, and for this purpose metal junction boxes are to be preferred. These, with suitable fittings, make electrical contact with the metal sheathing.

For surface work, switches, plugs and light fittings are invariably mounted on wooden blocks which are grooved and shaped at the back to fit neatly over the cable. This prevents dampness creeping through behind the fittings where it may cause trouble.

Rubber-covered Cables.—In many large houses tough rubber, or cab-tyre cables are used fairly extensively. They are usually run on porcelain insulators that hold them clear of the wall.

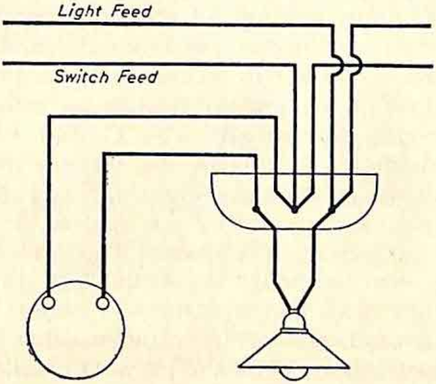


FIG. 27.—Looped-in twin conductors of lead or rubber-sheathed cables.

The lead and return conductors are incorporated in the one rubber sheathing. Joint boxes are reduced to a minimum by looping-in, as shown in Fig. 27. Live feeds to the lights and switches are run from light to light, thus linking up all the light-points in the circuit. A pair of wires is then run from the light to its controlling switch. By this method the ceiling rose or plate takes the place of a joint box, thus serving as an economical dual-purpose fitting. In this case three terminal fittings are used instead of the normal two terminals ceiling rose.

IX

INSTALLING DOMESTIC ELECTRICAL APPARATUS

PRIOR to 1921 the generation and distribution of electricity in England was in a state of chaos; there were nearly six hundred separate and distinct supply boards, each offering power in various forms as direct, single-, two- and three-phase, and in frequencies ranging from 25 to 100 cycles per second. The Central Electricity Board was appointed to control and examine the state of affairs and decide on a national frequency and supply voltage. Hence, the "National Grid" was evolved, and to-day single-phase electricity at 200–250 volts 50 cycles is the domestic source of power. Although the methods of generating and distribution have marched forward almost too rapidly for the demand, the local contractor often lives in the past; his methods are good and his work excellent, but he is still content to instal single switches and lamps, and two-point control is his main achievement. Who is to blame? Not the householder, for his lack of knowledge may exempt him; therefore we must turn to the contractor. A little extra consideration and thought, and an extra switch or two, will save electricity as well as time and trouble.

All stairways should have two-point control, and generally this could be greatly improved by fitting a third switch. Consider the case of stairs leading from one floor to the next with several rooms opening on to each landing; a convenient installation would have a switch by each door so that each individual controls the light. Electric bells have also remained in the past; one still sees a single bell and push, and although it serves its purpose quite well, the extra convenience obtained by adding another push is desirable. See also Chapter XIX.

Fitting a Door-bell.—Start with the simplest case—a battery operated push and bell for the door. To commence, examine the site, and then choose a place for the bell and a suitable place in which to conceal the battery. It will now be necessary to estimate the length of wire required and the manner in which it must be run. For exterior work, select a brass weather-proof push of the flat-back type (with these it is not necessary to make a recess in the door; see Fig. 28), drill a hole through the door to enable the wire to pass through, and then fix the push over the hole with two screws.

Conceal the wire attached to the push behind picture rails, skirting-boards, and under floors, and fix into position with insulated staples. When wiring in damp places, as under floor-boards, etc., arrange the wire in a slack loop between adjacent staples so that moisture will not drain down on the staples and cause corrosion. Figs. 29–32 illustrate various simple circuits.

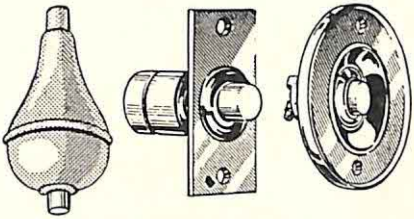


FIG. 28.—Three types of bell-push. That on the left is a "pear", and the other two are for exterior work.

Wire Sizes.—Various sizes and brands of single and double bell wire are on the market. The latter consists of two wires bound up in the same sheath, and insulated with rubber and cotton impregnated with paraffin wax. This is suitable for most work, but in cellars, where damp walls cannot be avoided, a variety of tough rubber-sheathed wire is necessary. This wire can be buried directly in plaster when wiring up new buildings, and is suitable for all damp and exposed work. The sizes are generally Nos. 18 to 22 S.W.G., and the wire selected will depend on the current necessary to work the bell, and also the length of the runs. It will be found that the resistance of a circuit of No. 22 wire is considerable, and if a large bell is installed, the voltage drop will be sufficient to cause the bell to be almost inaudible.

While on the subject of wires, bell-flexes must be considered, which, although of a thinner and much lighter gauge than ordinary wireless and electric-lighting flex, are far more flexible, being rather like a soft string in appearance. The insulation consists of twisted silk, there being no inner rubber covering. The size most suitable for domestic purposes is generally 10–40 gauge, with either thick or thin insulation. If it is necessary to put a push in some position where it will be subjected to hard work and rough usage, as in a garage or workshop, use ordinary electric-lighting flex of the best quality and of the necessary current-carrying capacity; 5-amp. flex is mostly used.

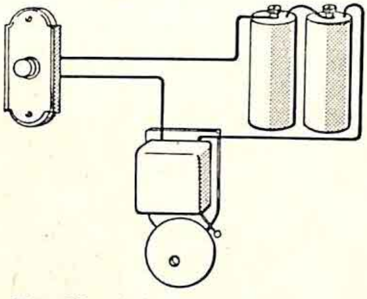


FIG. 29.—A bell operated by one push.

The Bell.—It will be found that bells fitted with 2½-in. or 3-in. gongs will serve for all average installations. Breakdowns caused by bad contacts, etc., can all be reduced to the absolute minimum by careful selection of the components. Bells are made with self-cleaning contacts, and all adjusting screws must have locknuts fitted. For exterior work, an enclosed water-tight bell is needed, and if this is liable to damage, it should have a cast-iron frame and cover.

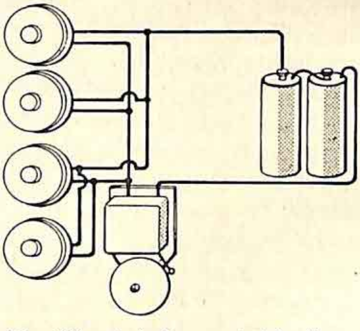


FIG. 30.—A bell operated by four pushes in parallel.

The Power Supply.—For the power supply there is only one method which gives absolute satisfaction when installed, and that is the bell transformer. Accumulators should be used only when they can receive expert attention, and on bell work, even though special cells are made, these are liable to be neglected, and consequently ruined. Wet or dry Leclanché cells are eminently suitable, as, once installed, they never require attention until run down, when either a new zinc or cell is needed. The wet cell is the cheapest in the long run, as it only occasionally requires a new element, and solution costs a matter of a few pence.

Primary installations can be considerably improved by observing some very simple precautions. Place the batteries in a dry place where they will not be interfered with, grease all terminals, solder all connections with a non-corrosive flux, and bind the join with insulating tape, making sure that the terminals are well screwed down. To prevent evaporation of fluid, pour paraffin oil to a depth of $\frac{1}{2}$ in. in the open jars. A position where variations in temperature are liable to occur should be avoided. The ideal battery for a bell installation is a nickel-iron accumulator, as these do not sulphate or lose their charge, and have an unlimited life. Whatever your type of battery, use good-quality Vaseline on all screw connections.

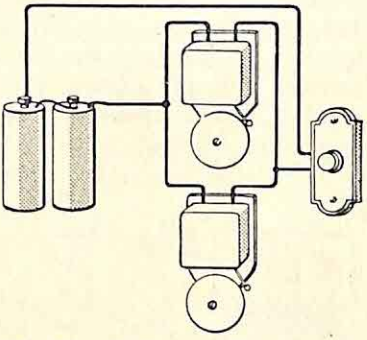


FIG. 31.—Bells in parallel operated by one push.

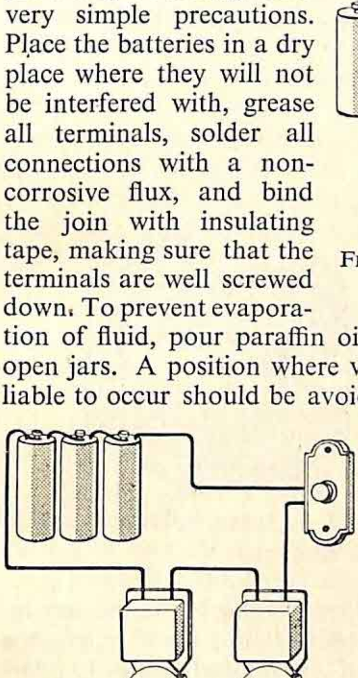


FIG. 32.—Bells in series operated by one push. Note that an extra cell is needed, due to the increased resistance of the second bell.

Alternating installations offer many advantages over battery sets, the chief of which is that, once installed, they never need any further attention. Ordinary bells, pushes, wire, etc., can be used, as the external characteristics are the same as for a battery bell; but a much better plan is to use a proper A.C. bell, as this has no contacts, and thus one of the frequent causes of trouble is eliminated. Their cost is the same as for direct-current equipment.

Fixing and Wiring the Transformer.—The fixing and wiring of the transformer should not present any difficulties. But some people seem afraid of these, and instead of tackling the job properly, they connect up to a power-plug through a length of flex, which is a practice not recommended. The simplest way of doing the work is to have a small plug wired up specially for the transformer, and then the latter can be removed for alterations to the circuit. Mount the transformer by the distribution board in, say, the pantry, so that it is well out of the way and cannot be interfered with by children, and make the high-tension leads as short as possible. A fuse should be included in each wire of the circuit, and the socket mounted a few inches above the transformer. The transformer is connected to the socket through a few inches of flex and a plug, which can be of the two-pin type. After completing the low-voltage side of the wiring, connections can be made to the transformer, and the circuit can then be tested. Use the lowest voltage tapping which gives satisfactory results, and

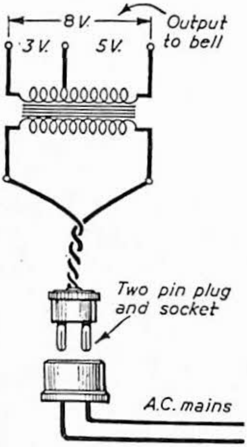


FIG. 33.—(*Left*) Transformer connections for an A.C. bell.

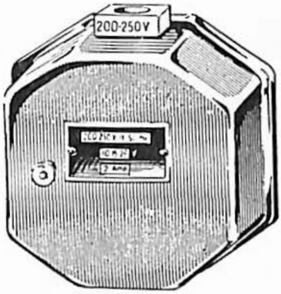


FIG. 34.—A typical bell transformer.

if the 3-volt taps are quite successful, do not connect to the 8-volt tappings.

Bell transformers are sold especially for this purpose and should be of good quality and make. They should be made in a moulded bakelite or similar insulating case, and be provided with a good cover held in place with screws. The output will be tapped to give voltages of 3, 5 and 8 volts, and these terminals should be at the opposite end of the case to the H.T. ones, and must be protected by the case (Fig. 34). In making connections to the transformer be quite certain that no stray strands of flex are left loose, as, if these should touch another terminal, serious damage could be done. Whatever your installation may be, and however simple, make a test before finally deciding that everything is complete. Use an insulation tester if possible, but failing this, a dry battery of over 10 volts and a sensitive voltmeter will do. Make sure that the fixing staples do not cut through the insulation of the wire, otherwise a short circuit will result.

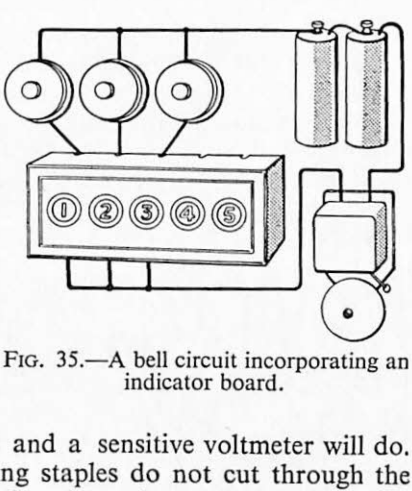


FIG. 35.—A bell circuit incorporating an indicator board.

All bell systems are based on the above simple installation; thus, once the components have been described it only remains to give a circuit, so that readers can wire up for themselves. Of course, complicated circuits will need a little description, but the application of these to domestic use is not often necessary.

When a bell is operated by two pushes, complications arise as to which push has caused the bell to ring, and so an indicator board should be fitted, as, with three or more pushes, this becomes essential. The indicators consist of a small electro-magnet in series with each push, and in front of each magnet a freely moving pendulum armature is mounted, so that when the circuit is closed, it commences to oscillate and thus indicates from which point the summons came. This arrangement is quite suitable for most ordinary work, but when installing, buy a box with at least two more holes or windows than are actually required; thus if an extra push is added, it is only necessary to add a new indicator to the board, and connect it in series as before (see Fig. 35). The above type of indicator is only suitable when the person called is always within hearing distance of the bell, and will arrive at the board in time to see one indicator moving, but in those cases where the person may be some distance away, a mechanical reset movement is needed. This consists of a similar electro-magnet which comes into series with the push when it is pressed. The circuit is then closed and the indicator drops in front of the window, and is reset by pressing a small lever. See also Chapter X.

Electrical Indicators.—Electrically reset indicators can be obtained. It is not worth while making up one's own indicators, for it is cheaper to buy ready-made ones and mount them on home-made boards than to buy complete indicators. One such indicator is illustrated in Fig. 36, and circuits are shown in Figs. 37 and 38, and from these any normal connections can be worked out. It is sometimes necessary to have two bells in circuit, one with a high note and the other low, or one bell may be replaced with a buzzer. Such circuits are useful when wired up, as it is possible to locate the person ringing by the tone of the bell. In such cases the indicator boards can be mounted together or on separate floors. With long runs and indicators in circuit, it will be found necessary to have a larger voltage battery, and

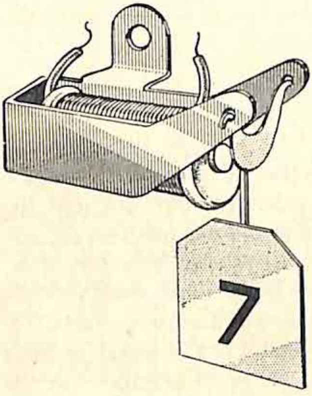


FIG. 36.—A useful bell indicator.

cells should be added until satisfactory working conditions result. It is in this connection that the transformer proves very useful. In exceptionally long runs a relay can be incorporated to operate the bell. Run double wire from the push to the relay and battery (a single cell would be sufficient to operate it), and the local circuit consists of a bell and battery.

Relays can often be used in the bell circuits to switch on lights and open and close other switches. Connect them in series with the bell-operating relay, and not in the bell circuit; otherwise, if a relay is connected in series with a bell, the intermittent current passing through it will not hold the contacts closed, so that apparatus in the local circuit does not function properly. If a bell is desired to be used in conjunction with a visible signal, this may be connected in series with it. It must, however, be of a small capacity, as a large filament will not heat up with the intermittent current, and this saves the cost of an extra relay and battery (see Fig. 37).

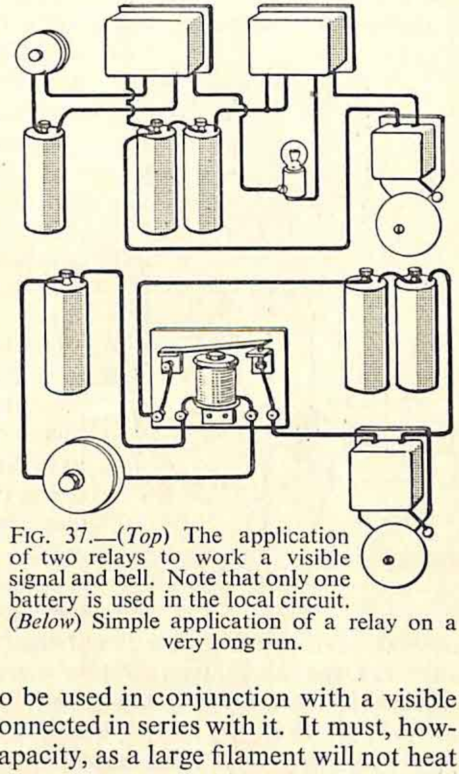


FIG. 37.—(*Top*) The application of two relays to work a visible signal and bell. Note that only one battery is used in the local circuit. (*Below*) Simple application of a relay on a very long run.

Burglar Alarms.—For burglar alarms a continuous-action bell is essential, since a cunning person might open a window slowly, hear the alarm start, and, of course, immediately close the window before the alarm has had time to awaken anyone. With the knowledge that alarms are fixed he can beat a safe retreat, or, if determined to enter the house, dismantle the alarm. This is possible unless it is so fixed that the circuit is closed even when the glass is removed. With an ordinary bell circuit, it is possible to close the circuit and open it again so quickly that the bell gives only one or two feeble strokes not sufficient to awaken even a light sleeper. A continuous-action bell prevents this, since once the circuit is closed the bell will ring until reset (Fig. 38). See a later chapter for further burglar-alarm systems.

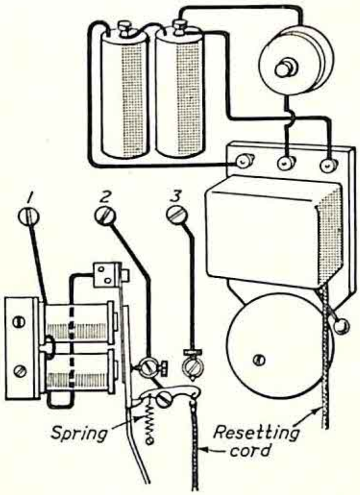


FIG. 38.—The circuit and wiring for a continuous-action bell.

A letter-box alarm is very simple to construct and install, and is wired in parallel with the front-door bell, so that if an indicator circuit is used, the summons will come from the front door. The components are often cut from 16-in. sheet brass, and may be fixed directly on to the door, or mounted on a small panel (see Fig. 39). The contacts are so arranged that they only close the circuit while the letter is actually being pushed in, thus the bell will only ring for a few seconds. This has the advantage that if a newspaper is pushed in and left in, the bell will not ring continuously, which would prove most annoying if the paper was brought some time before the household's awakening. Wires are connected to the moving arm and the side bracket, and this is bent so that when the arm is pushed out through 40 deg. it makes contact, but on pushing it further the contact is opened and the bell stops ringing.

Clean Contacts.—The improvements that can be made to quite an ordinary circuit without affecting the main wiring are many and varied, and it is to these little extra points that attention is drawn. The user sees nothing of the wiring or battery; it is only the pushes and their arrangements that concern him. For bedrooms, all pushes should be fitted with an extension socket, so that in times of illness it is only necessary to plug in a pear-push and length of flex to reach to the patient's pillow (Fig. 40). Where pear-pushes are fitted in an invalid's room, these also should be provided with sockets so that extension wires may be fitted. This will be found very useful when a person moves from a bed to a window-seat; the extra push is removed at night-time so as not to be in the way. In studies and offices extensions are often needed, but these should take the form of flat-backed pushes with the flex leaving through a bushed hole in the side. They are also very useful in a dining-room, and do not look out of place on the table, if they are of the china type (see Fig. 41). Sometimes an extension bell is required, and this should be connected in parallel with the usual bell. In such cases a small two-pin socket is connected in parallel with the bell, and the extension bell has a two-pin plug attached through a long length of flex. Extension-bell sets are often very useful, and consist of a small bell and single dry cell mounted in a small portable case, which is connected through a length of flex to a pear-push.

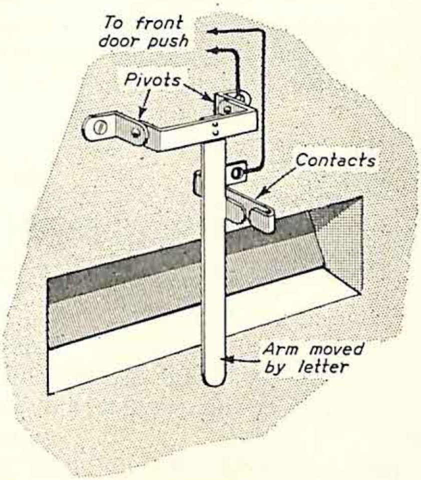


FIG. 39.—A home-made letter-box alarm.

Locating Faults in Wiring.—Faults in bell circuits are comparatively easy to locate, due to the shortness and low resistance of the runs. If the bell starts ringing and continues to do so even when the push is disconnected, it indicates that there is a "short" on the push circuit, most probably caused by a staple. When a bell will not ring, test the battery with a voltmeter, preferably one of low resistance, examine all contacts, and if these seem the least doubtful clean and smear with vaseline. Repeat the procedure for the push and bell, as it is important to clean all contacts, since it may be the cumulative effect which is causing the trouble.

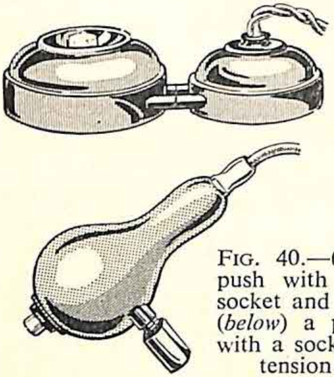


FIG. 40.—(*Above*) A push with extension socket and plug, and (*below*) a pear push with a socket for extension leads.

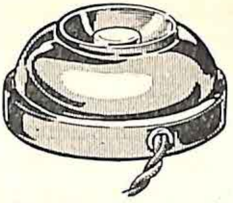


FIG. 41.—A push with side leads for operation on a desk, etc.

The Lighting Circuit.—Before attempting any alterations to lighting or power circuits, one must be quite familiar with the wiring rules and regulations, and in cases of hire-purchase installations one must make application in writing before any alterations are undertaken. A summary of the important rules is given in an earlier chapter. The two-point circuit is perhaps the most useful that can be applied to domestic work, and every room that has two doors or entrances should have a switch by each door; in theory this seems obvious, but in how many cases is it installed?

Bedrooms should also have two-point control, a two-way switch being fitted by the door and a two-way pear-push on a length of flex over the bed. In the case of corridors with stairs and several doors opening on to them, three- and four-point control can be fitted—in fact, there is no limit to the number of points that can be installed. In changing a circuit to two-point control, first examine the present one and determine the feeding wires, also obtain the necessary cable of the correct size, and two two-way switches or a two-way pear-push. With a pear-push it is necessary to have a three-plate ceiling rose, from which the switch is suspended on a length of triple flex. It should not be long enough to reach the floor, and make sure that the new switch will fit in or on the same panel as the old one.

Having determined which are the two live cables, the one connected to the lamp is not touched, but that to the switch is marked, and the other wire from the switch to the lamp is removed. The free terminal of the lamp is then connected to the arm of the new two-way switch, and the live wire connected to the arm of the two-way switch that is fitted in place of the original one. The two side terminals on the two switches are connected together (see Fig. 42). With a ceiling rose, the flex is connected up after it has been screwed in place, and the triple flex is made by winding a single strand round a length of double wire. If two lights are wanted instead of one, the addition is connected in parallel with the existing one, and this is a simple case of looping (see Fig. 43). If the added light is a reading-lamp, this can have its own switch in series, or, on the other hand, so that the added lamp shall be independent of the existing switch, it must be connected on the live side of the switch.

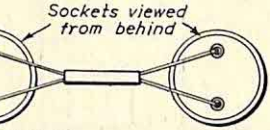


FIG. 43.—Simple example of looping.

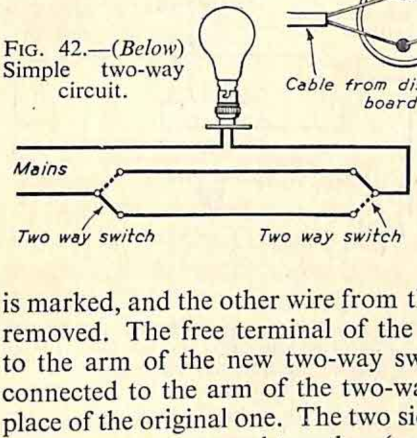
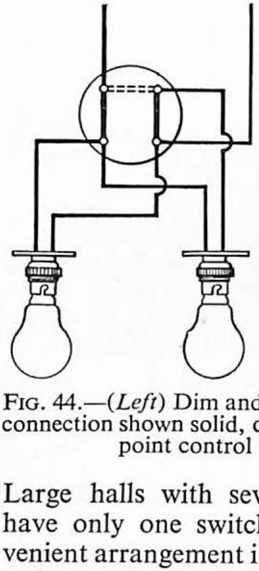


FIG. 42.—(*Below*) Simple two-way circuit.

Special series-parallel switches are on the market, and are very useful in cases of corridors and passages, etc.; two small-candle-power lamps can be wired up so that for normal working they give the maximum light, i.e., in parallel, but if the passage is only used occasionally they may be left in series; this is very useful when children are running about, as the dim light prevents accidents, but the saving soon pays for the cost of installing. Fig. 44 shows dim and bright controls, using a special switch.

Three-point Switching.—Three-point control has as many if not more applications than two-point, and has advantages.



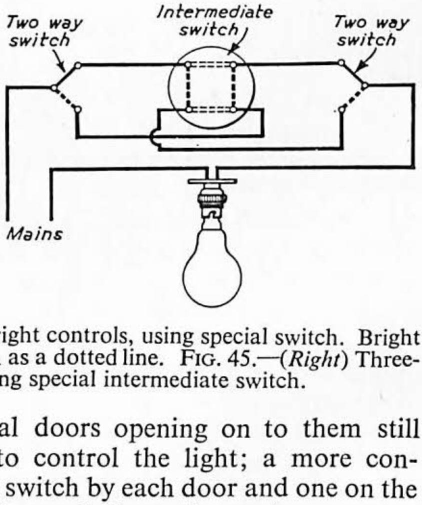


FIG. 44.—(*Left*) Dim and bright controls, using special switch. Bright connection shown solid, dim as a dotted line. FIG. 45.—(*Right*) Three-point control using special intermediate switch.

Large halls with several doors opening on to them still have only one switch to control the light; a more convenient arrangement is a switch by each door and one on the stairs or the landing above; bedrooms opening on to a common landing should also have a switch at each door. Three-point control is a useful development of two-point; two two-way switches are needed for the first and last switches on the run; the other switches are of a special type of double-pole changeover, known as intermediate (Fig. 45). If you are not familiar with this circuit, then wire one up on the test bench, using a dry cell and flash-lamp bulbs; the two end switches can be of the usual type, but for the intermediate use a double-pole changeover of the wireless type, so that the connections and changes are clearly visible. The trouble expended on this will be well repaid when doing the actual installation. It will be noticed that only two wires are run between the switches, no matter how many are connected up. Four connections are made to the intermediate switches, and in the circuits these are shown as small circles joined up with a dotted line. Instead of using the intermediate switches, two two-way may be used coupled up both mechanically and electrically (see Fig. 46). These two switches should be mounted on the same panel, but are not so neat or easy to install as the intermediate; do not forget that the two end switches are ordinary two-way. As mentioned above, any number of control points can be added, the sketches showing them for two- and three-point control.

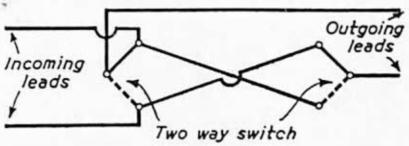


FIG. 46.—Mechanically and electrically coupled switches, for multi-point control.

Wireless and Clock Points.—In these days of mains sets it is desirable to install a new point for their operation; the simplest way of doing this is by looping from a nearby power-point, but this has many disadvantages, apart from the interference caused when the plug-point is put in use. In the first place the set depends for its protection on a pair of heavy duty fuses, perhaps 15-amp. rating; and secondly, the system may be overloaded. The best method is to wire up the point separately, taking leads from the bus-bars and including a fuse of the correct value in circuit; these plugs need not be of the power type, but it is often an advantage to use an interlocking switch-plug, as this will save interference when the set is in use. The same notes apply to electric clocks—the makers often include a sketch illustrating how the clock is to be connected by looping to a power-plug; this system is quite satisfactory, but has the disadvantages outlined above, also the use of heavy consuming devices at the plug may cause the clock to stop or fall out of step. I have noticed this happen when a large fire was switched on. The clock was in parallel with the plug.

Power-plugs.—Domestic appliances are generally used on the power circuit and provided with a suitable plug and earthing connection. All power-plugs must be fitted with an earth-pin, and the connection made and broken according to the conditions which are specially laid down in Home Office Regulations dealing with the use of electricity in workshops and similar places. Domestic apparatus is rarely properly earthed, generally because the householder fits the plug himself, the contractor having installed the socket. To earth an electric iron, drill a hole in the metal support and pass a nut and bolt through. The wire is then twisted into a loop and secured. Special plugs are available with earthed projections that make contact with the iron frame; these are quite useful, but the above method is to be preferred. The normal domestic flat-iron receives very rough treatment, often being knocked on to the floor and left on until nearly red hot; thus it is advisable when connecting up to use the best possible connector and three-core flex. Some electric flat-irons are provided with a safety device to prevent over-heating.

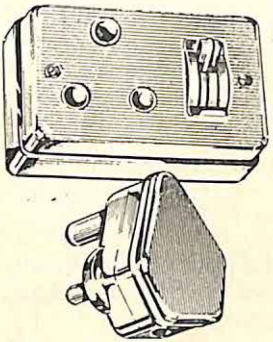


FIG. 47.—Switch plug with interlocking arrangement.

Electric Fires and Irons.—Electric fires and irons in the small sizes are generally sold with an ordinary adapter for use on the electric-light point, thus these are not provided with an earthed point. Whenever possible use power-plugs, but in cases where power is not laid on fit special earthed adapters; in these the pin is provided with a connection so that it may be connected to the frame of the apparatus being used. The lamp-holder is also earthed, and connection to earth from the apparatus is made by the pin of the adapter touching the holder.

In positioning power-plugs always try to ascertain for what purpose they will be used—for example, in a kitchen a plug is needed for an electric iron; thus it can be mounted 3 ft. above the floor; this saves flex and is very convenient to use, since the plug will be at the table height or slightly above it. Place sockets so that plugs can be withdrawn easily, and at such a height above the floor that the hand can be put all round to obtain a good grip. When installing plug-points for operating a vacuum cleaner, do it so that the greatest area can be "covered" by each plug; these areas should overlap.

The Garage.—The home garage is generally completely neglected, and if the owner has a single light installed he may consider himself suited. In these days of economical battery chargers, which revive the battery over-night, some form of power-plug is a necessity. It should be installed in an accessible position fairly high up on the wall; a switch-plug (Fig. 47) would be more convenient than an ordinary one. If the complete apparatus is mounted over the bench it will form an ideal home-charging station. Mechanically coupled switches should be mounted on a small panel before installation as shown in Fig. 48.

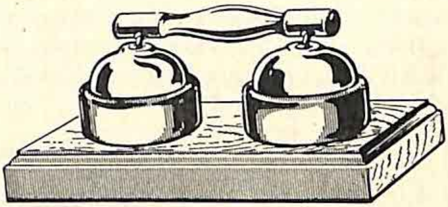


FIG. 48.—Mechanically coupled switches should be mounted on a small panel before installation.

Fittings and Accessories.—Plastic is popular to-day—switches, holders, adapters, and anything that can be moulded is made in this or similar material; the shock-proof skirted holders are very good, as are the adapters, but for switch covers the material is hardly strong enough. The modern tumbler switch has a composition or porcelain base, but the cover is of plastic and is only strong enough to afford electrical, not mechanical protection. Their advantage is cheapness, but the installation is not to be recommended in places where the treatment is liable to be rough.

X

INSTALLING ELECTRIC BELLS

TO-DAY there is an electric bell in almost every home, and to the junior electrician the installation of one is not a difficult task. In this chapter information as to bells, batteries and wire is given, so that installing and maintaining the system will present no difficulties (see also Chapter IX).

Bells.—Bells are made in various shapes and sizes, and with different gongs, which are classed as Round, Sheep and Church. For general housework a 2-in. or 3-in. round gong will be large enough, but for other uses gongs up to 12 in. in diameter are made.

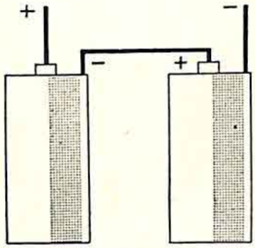


FIG. 49.—Batteries connected in series.

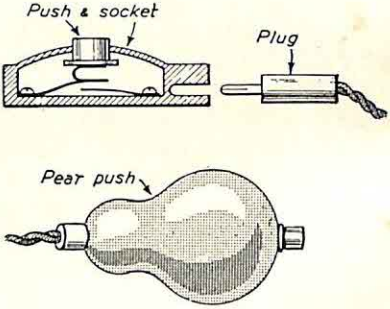


FIG. 50.—Types of pushes.

Wire.—This should be of No. 20 or 22 double bell wire. This form of wire is exceptionally useful and very easy to fix in awkward positions, as only one staple is required to hold it. Fibre-insulated staples should be used, as with these there is no fear of the staple cutting the insulation if it should be driven in too hard.

Batteries.—A single dry or sal-ammoniac cell is generally sufficient for the average house-bell circuit, but if 50 yds. or more of wire are used, then two batteries will have to be used, connected in series (see Fig. 49). Sal-ammoniac works out cheaper than dry cells, but they are not quite so trouble-free as the latter. Some firms market a special bell battery of 4·5 volts, which has about three times the capacity of a pocket-lamp refill. In cases of emergency, pocket-lamp refills may be used on the house circuit when the usual battery has failed. It is not a good plan to use accumulators on bells, as they require frequent charging and are liable to get damaged by neglect.

Pushes.—These may be of any type, provided that they make good contact when pressed. For an outside and exposed position use a watertight brass barrel push suitably inscribed. Firms engrave pushes to suit their customers with such words as Visitors, Nights, Servants, etc., etc., for very little cost. In the bedroom an extension push should be fitted so that a pear-push may be plugged in circuit and placed within easy reach of the bed. In case of illness these pushes are very useful, as the pear-push may be placed on the pillow by the patient's head, thus causing very little inconvenience (see Fig. 50).

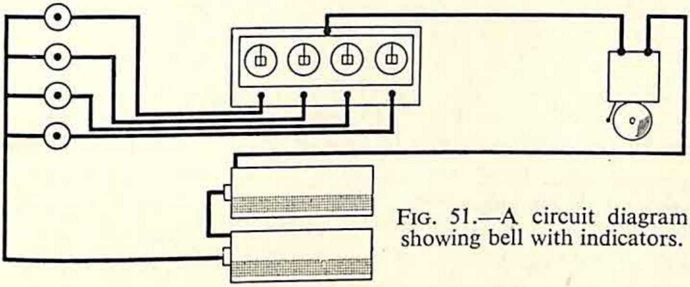


FIG. 51.—A circuit diagram showing bell with indicators.

When two or more pushes are used to ring the same bell, an indicator should be connected, as explained previously, so that it may be determined which push has caused the bell to ring. The indicators are sold with any number of holes, labelled Front Door, Back Door, Hall, etc., etc., and each movement is connected in series with the push in that particular room. The indicator consists of an electro-magnet arranged so that it can attract a card to which a soft iron armature is fixed. When the bell rings, current passes through the indicator coil and causes the card to move; as the card is displaced it continues to swing even when the bell has stopped ringing, so that even if the indicators are not under observation when the bell rings it is quite easy to determine a few seconds later at which point the push was pressed. A circuit diagram showing bell with indicators is given in Fig. 51.

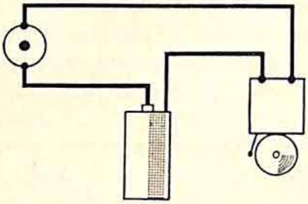


FIG. 52.—A simple bell circuit.

Wiring a Bell Circuit.—Fig. 52 shows a simple bell circuit. In wiring up a bell circuit, two points should always be before the worker: first, to keep the wire as short as possible, and, secondly, to keep it out of sight as much as possible. Connect a wire to the push by means of the small screws provided, and mount it in the required position, pull the wire tight, and, keeping it so, lead it up to the picture rail, behind which it may lead round the room to the door; and use one staple for every 18 in. of wire. An alternative plan is to take the wire below the floorboards, as this keeps them both short and out of sight (see Fig. 53); lead the wire to the position for the bell and battery and cut it, leaving about a foot to spare. Do this for any other push that is required, leading the wire to the same place. If the bell and battery are not placed side by side, a little single bell wire must be used to complete the circuit.

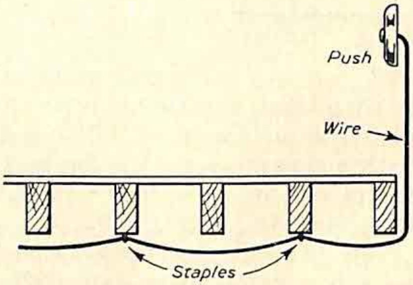


FIG. 53.—The method of wiring below the floor.

Testing Bell Circuits.—If a bell fails to ring, first examine the push and clean all the contacts and tighten up the wire, tighten the contacts on both the bell and battery, and test the battery with a lamp or spare bell. If all is found to be in order, then there is a broken wire in the circuit. Take two stout darning-needles and solder them to the ends

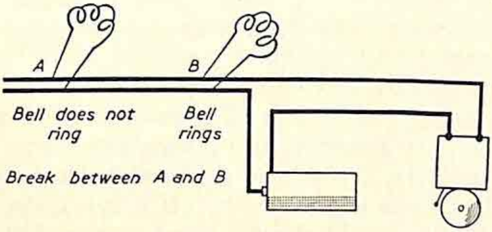


FIG. 54.—Locating a break in the wire.

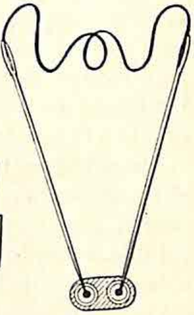


FIG. 55.—A testing device.

of a piece of insulated wire, push one needle through the insulations of the wire until it touches the wire; now repeat on the other wire with the other needle. If the bell rings, then the break is nearer the push; if it does not then it is nearer the bell (see Figs. 54 and 55).

XI

HOME-MADE BURGLAR ALARMS

ONE often hears the subject of burglar alarms discussed in terms of mystery. In fact, they are nearly as simple as the household bell system.

There is one decision to make. Shall the burglar alarm be obvious, so that its presence scares off intending intruders (which might also have the effect of drawing attention to valuables), or shall it be hidden and the householder rely solely on the effectiveness of the system? If you intend to take the first alternative, fix the alarm bell in such a position outside the house that no one, even at night, can fail to see it, but at the same time make absolutely certain that it cannot be reached, thus giving anyone the opportunity to prevent it ringing. The alarm bell should, however, be the only thing which is noticeable, all other devices, wires, etc., being well hidden or protected to prevent tampering.

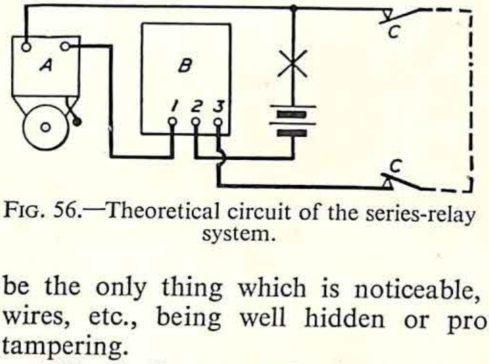


FIG. 56.—Theoretical circuit of the series-relay system.

A Simple System.—The simplest system is one in which movements of a door or window cause contacts to close, thus completing the circuit and ringing the bell. There is, however, one serious disadvantage in this system, for it is only necessary to cut or break the wires to stop the bell from operating. Should the intruder notice wires and contacts attached to a window it would be quite a simple matter for him to take a piece of glass out and then cut the wire, so that the window could be fully opened without operating the alarms. The next best system, and one which will be advised for ordinary conditions, is an arrangement of contacts in series with each other, continuously closed, and in which the alarms operate only when the circuit is broken. Immediately this happens the alarm bell rings, and even if the series circuit is made again, the bell will still keep on ringing until such time as it is purposely and deliberately stopped.

A third system, which works on the Wheatstone Bridge principle, is generally considered the most effective, even against the expert house-breaker. This system is "set" with the resistance of the alarm circuit balanced against that of an adjustable "arm", and any alteration in the resistance of the alarm circuit is sufficient to operate the system. If the intruder cuts the wire or tries to be clever and short circuits the contacts, which he hopes later to separate safely, the balance is upset, and as these systems are generally balanced very closely, no method can be devised by unauthorised persons to upset the circuit and retain the balance. However, this system requires continual attention and is not advised for ordinary household work.

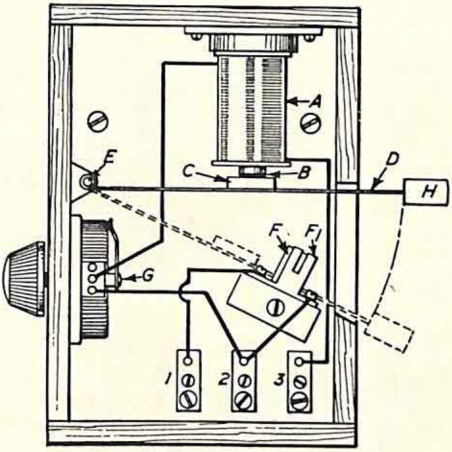
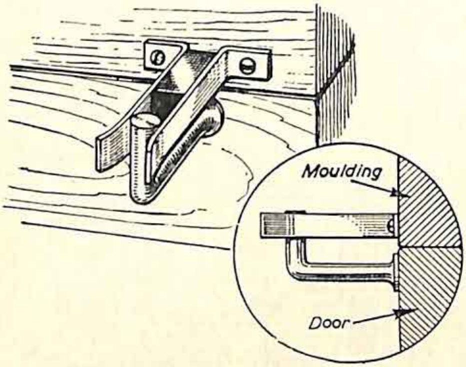


FIG. 57.—The relay shown can be purchased, but without the variable resistance, which is included to reduce the current passing to the most economical value.

A Series-relay System.—Fig. 56 shows the main details of the series-relay system which is advised. "A" is the alarm bell, "B" the mechanically reset relay, and "C" the contacts arranged in series throughout the house. The bell is just an ordinary electric bell, which can be obtained quite cheaply.

If it is intended to put the bell outside the house, then a more expensive waterproof type should be used. The relay, shown in detail in Fig. 57, can be purchased, but without the variable resistance, which is included purely to reduce the amount of current passing to the most economical value. "A" is a pair of coils taken from an electric bell and mounted firmly on the top of a wooden box. The faces of the cores are covered with a thin disc of paper, "B", to make sure that the armature, "C", will come "unstuck" when current "A" fails. The armature is riveted to the brass arm, "D", which is pivoted at "E". This pivot should be quite free and must allow the arm to fall easily into the two contacts, "F" and "F_1", which are made of thin but very springy brass. "G" is a standard 400-ohm potentiometer used for radio purposes. Beyond these details little more need be said, except that a cover should be placed over the top of the box, leaving only the resetting knob, "H", and the resistance visible. The box should be fixed in a place as remote as possible from any point where an entry might be made, probably an upstairs room is best of all. The alarm bell should be fitted in a position where it can be easily heard both inside and outside the house, but out of the way of possible interference. When the rest of the system has been completed and all contacts closed lift the arm, "H", against the pole pieces and adjust the knob of the resistance so that the arm just holds up. Some allowance might be made for vibration dislodging the arm. Further economy in current



FIGS. 58 and 59.—The type of contact which covers most positions where the door moulding juts out over the door; an ordinary cupboard hook provides a satisfactory key.

can be effected by rewinding the coil bobbins with 36 or 38 S.W.G. d.s.c.

Usually two 1½-volt bell cells will be ample to operate the system nightly for many months. A switch should be inserted into the battery lead at "X" (Fig. 56) to render the gear inoperative when not required. In testing the system at night, when the ringing of the alarm bell might unnecessarily disturb others, an ordinary flash-lamp bulb can be inserted across the bell contacts and the bell disconnected while the tests are made.

Effective Contacts.—The contacts, described later, should be placed in every conceivable place where an entry might be effected.

Every possible point should be covered, even roof-traps, skylights and pantry windows. The various types of contacts which are required are very numerous, and only a few are described here. The main thing to avoid in these contacts is flexible wires or wires attached to moving parts which may be a cause of non-operation later. Fig. 58 shows the type of contact which can be used in most positions. One of the contacts has a piece of fibre or ebonite fixed to it to prevent the contacts closing together, connection between the two parts being made only when the key-piece is inserted. The contacts are screwed to the top of the door or window surround and the key, which can be a stout brass screw with the head cut off, is driven into the door itself. The connecting wires are best soldered to the foot of the contacts. Where the door moulding juts out over the door an ordinary cupboard hook provides a

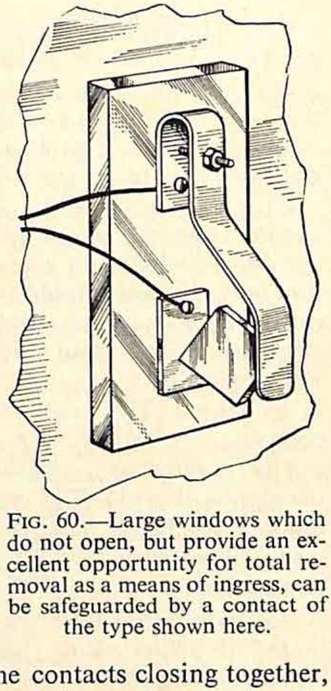


FIG. 60.—Large windows which do not open, but provide an excellent opportunity for total removal as a means of ingress, can be safeguarded by a contact of the type shown here.

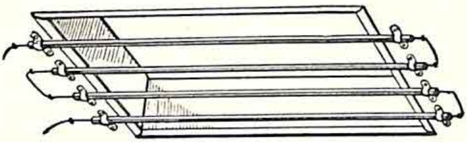


FIG. 61.—A suitable arrangement for safeguarding a skylight by means of a thin insulated wire passed through bars made of split conduit, and connected as shown.

satisfactory key, and is shown in operation in Fig. 59. The coloured lacquer must be cleaned off the brass before such hooks are used, because it is an insulator.

Contacts for metal windows must be mounted on ebonite blocks, which are then secured to the iron frames with metal thread screws, it being necessary to drill and tap in these cases. It might be found that the metal windows are insulated from one another in some cases, but it is always advisable to insulate the key-piece as well.

Large windows which do not open, but provide an excellent opportunity for total removal as a means of ingress, can be provided with a contact of the type illustrated in Fig. 60. The base should be a thin slip of ebonite and the upper contact of $\frac{1}{8}$-in. strip brass. The lower contact is of thin springy brass and just sufficiently strong to hold the solid brass key up in position. The complete contact can be secured to the glass with sealing-wax or Page's glue. The best position is in the centre of the window, but the device is effective even at the edges. The device operates by the inertia of the key. When vibration shakes the window, the device shakes with it, but the key

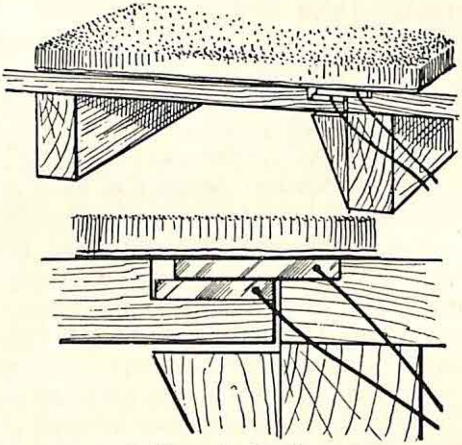


FIG. 62.—Suitable and effective contacts that can be arranged under a mat.

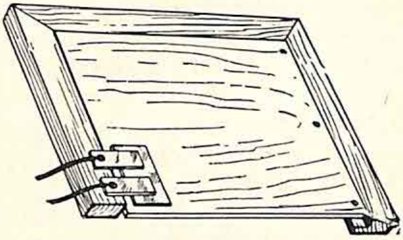


FIG. 63.—Another under-the-mat type of contact which is very effective.

tends to remain steady, and pushes the thin spring outwards, and relieves the pressure on the solid contact, with the result that the key drops out and breaks the circuit. Precautions and care in making and adjusting the thin spring must be taken to ensure that wind or traffic vibration will not cause the key to fall out.

Where a window or a skylight can be barred, $\frac{1}{2}$-in. split conduit can be used through each bar of which a thin insulated wire is passed and connected, as shown in Fig. 61. Ordinary pipe saddles can be used to secure the bars. The effectiveness does not lie in the strength of the tube, but in its weakness. No. 36 S.W.G. d.s.c. wire is suitable for use.

"Under the Mat" Contacts.—These can be arranged as shown in Figs. 62 and 63, the first being suitable for wooden floors and the second on stone or tiled floors. Outside gates can also be contacted, a satisfactory form being shown in Fig. 64. The two contact plates are screwed to the gate-post and the key-piece made from springy brass to the gate itself. Used in such a position the contacts are invisible and also protected from the weather. The wires are passed right through holes drilled in the gate-post, as shown in Fig. 64. All outside

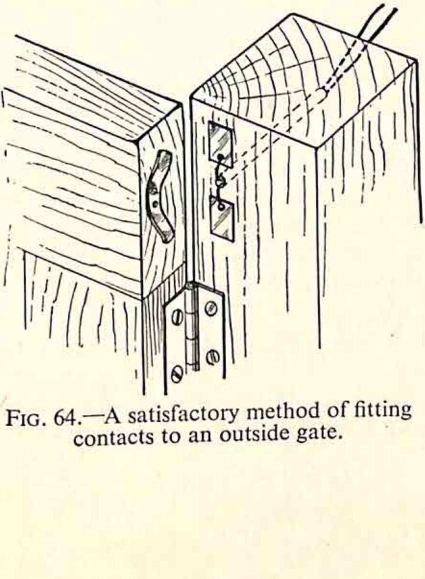


FIG. 64.—A satisfactory method of fitting contacts to an outside gate.

wires should be lead covered and hidden wherever possible, whilst those inside can be of 26 S.W.G. d.c.c.

Fig. 65 shows the essentials of a piece of apparatus which is necessary under the following conditions. If a contact is fitted to the front door, the last person out will trip the main relay, merely in the act of opening the door to pass through, and it is impossible for the main relay to stay "up" if the door is left open. To overcome this a special "out" relay is required which makes the door contacts inoperative until they are closed. "A" in Fig. 65 represents the door contacts which must be open before the system can be "set". The lever "B" is then raised so that the armature "C" is against the core of the magnet "D". The point of the trigger "E" will keep it in position mechanically until such time as the main relay (Fig. 57) is closed. When this happens the coil "F" attracts the armature "C", and releases the trigger "E", which, however, does not fall owing to the line current traversing the coil, "D". However, when the door is shut and the contacts "A" close, the coil "D" is short circuited and the armature "C" drops clear, the armature "G" still being held against "F" and the contact "H" broken. This leaves the door contacts "A" in charge, and should these be opened, then the alarm bell will ring in the normal way. Fig. 66 shows a pictorial sketch of the contact suitable for the circuit given in Fig. 65.

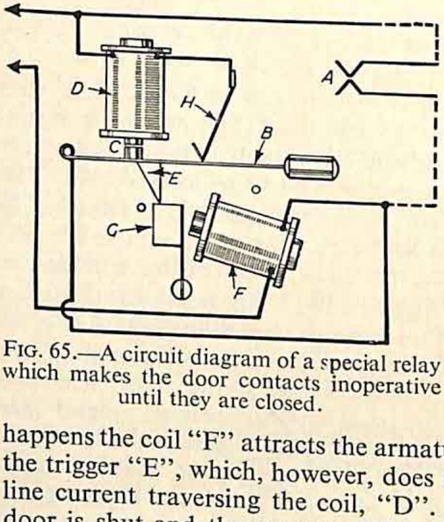


FIG. 65.—A circuit diagram of a special relay which makes the door contacts inoperative until they are closed.

Commercial Burglar Alarm.—Readers may be interested to know that there are a considerable number of burglar alarms obtainable on the market for quite a small outlay. These alarms take various forms and are generally of the make-and-break contact type. One consisting of a divided sphere, one half of which acts as a bell and the other half containing the mechanism, is an interesting example. The half containing the mechanism is also fitted with three legs, and then wound up by twisting the two halves in opposite directions; it is placed on the floor legs downwards. The weight of the device causes the legs to recede into the body and act as a check. When placed behind a door, window, etc., opening them will cause the ball to roll, thus freeing the legs and causing the bell to ring for several minutes.

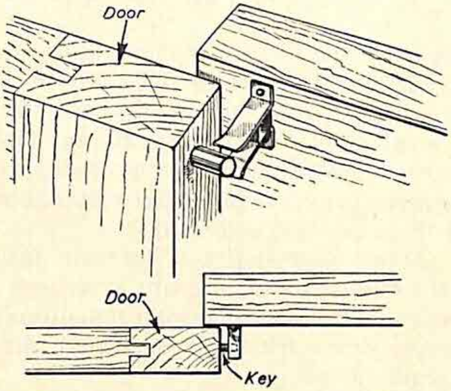


FIG. 66.—A pictorial sketch showing the contact suitable for the circuit shown in Fig. 65.

Door contacts suitable for operating burglar alarms can also be obtained very cheaply, and consist of continuous and trigger types. As a further safeguard against burglars, it is also possible to obtain special locking devices for locks which make them practically burglar-proof.

XII

ELECTRIC WATER HEATING

MORE than half a million electric water-heating installations are now in daily use in Britain. These range from the simple immersion heater installed in the conventional domestic hot-water storage tank to the large commercial installations having capacities of many hundreds of gallons to supply hot-water requirements of large blocks of offices, cinemas and so forth.

While the majority of hot-water installations conform to standard practice, so many diversions are possible in order to provide highly efficient installations that a wide variety of types of electric water-heater are made to suit particular requirements.

Types of Systems.—The chief types of electric water heating systems are:

(*a*) Immersion heaters, which are installed in the existing hot-water tanks in a horizontal position to provide hot water to one or more outlets. These may, in certain circumstances, also be installed vertically.

(*b*) Circular types of immersion heaters which are always installed vertically in existing cylindrical hot-water tanks and provide hot water to one or more outlets.

Both the above types may be used solely as electrical systems, or may operate in conjunction with a back-fired solid-fuel boiler or independent solid-fuel boiler of the "Ideal" pattern.

(*c*) Self-contained storage water-heaters, which serve one hot-water outlet.

(*d*) Self-contained storage water-heaters, which serve one or more hot-water outlets.

(*e*) Self-contained storage water-heaters which are connected to existing installations and operate in conjunction with solid-fuel, back-fired or independent boilers.

(*f*) Self-contained water-heaters which are combined solid-fuel storage tanks and electric water-heaters, and may be used in dual form or independently.

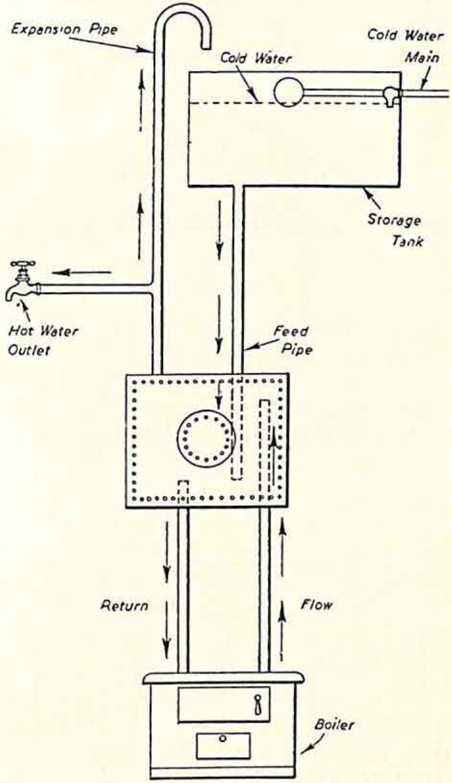


FIG. 67.—Diagram of a simple hot-water system showing how cold water from storage tank flows down the return pipe to the boiler, where it is heated, and rises up the flow pipe and is drawn through the expansion pipe upon the opening of a tap. A circulating system is created through the boiler and storage tank, which are linked as a complete circuit by the flow and return pipes.

No general rule can apply as to which system is adopted, since each proposed installation must, after careful inspection, be judged on its merits.

Hot-water Systems.—Main essentials of hot-water systems are: boiler, storage tank, cold-water cistern with ball-valve, overflow expansion and connecting pipes. Cold water flows at mains pressure into the cold-water cistern, the height of the water in the cistern being regulated by the ball-valve, and should this fail to operate when the water is flowing, the overflow pipe prevents damage from flooding. Cold water by force of gravity flows down the feed-pipe (Fig. 67), fills the boiler storage tank, flows down the return pipe to the boiler and is forced, by gravity, up the flow-pipe and eventually finds its own level in the expansion pipe, as predetermined by the position of the ball-valve. Water in the pipes is maintained at a pressure depending upon the "head" of water between cistern, tank and boiler.

Should one of the outlet taps be opened, cold water will flow, due to the pressure of the system. When the temperature of water is raised its volume increases. Increase in volume of water is at the rate of approximately 4 per cent. from tap temperature to boiling point. A given volume of water (for instance 1 pint) which weighs about $1\frac{1}{4}$ lb. when cold will weigh less when heated.

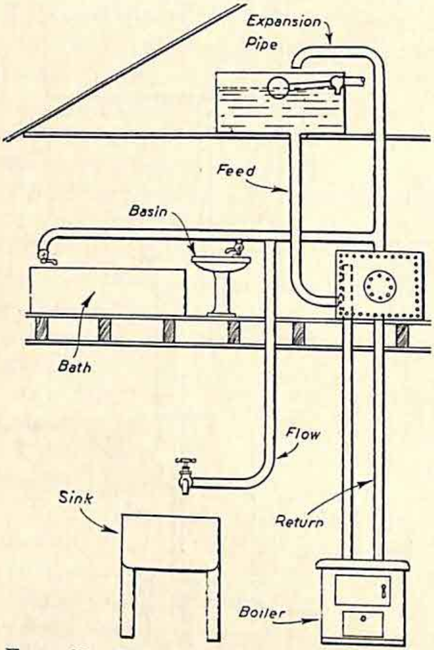


FIG. 68.—Solid fuel hot-water system showing the correct method where each draw-off point has been taken from the expansion pipe.

Being lighter, hot water also rises to the top of a vessel as it is heated. This is due to the heavier cold water sinking to the bottom of the vessel and forcing the lighter and warmer water to the top. This principle applies in the domestic hot-water system. When the boiler fire is lighted, the water in the boiler increases in volume and its temperature is raised. This is forced up the flow-pipe into the storage tank by the colder and heavier water "falling" down the return pipe. This system of primary circulation continues during the whole time the boiler fire is alight and heat is applied to the water flowing through the boiler. Unless water is drawn off at the outlets or the boiler fire carefully regulated, the water in the storage tank will tend to boil and hot water and steam flow out of the expansion pipe.

Difficulty of heat control is one of the chief disadvantages of domestic solid-fuel systems.

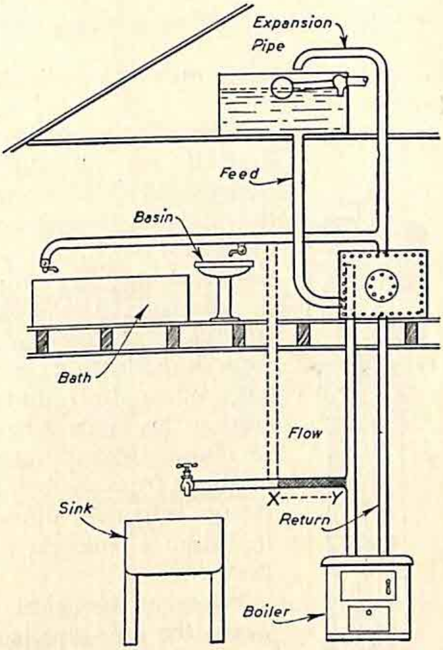


FIG. 68*B*.—Shows how in some cases one tap, usually supplying the kitchen sink, is bled from the flow pipe. The section *XY* is removed and a new pipe (dotted line) is inserted.

Converting Existing Installations.—In London and S.E. England, which are hard-water districts, hot-water storage tanks are usually rectangular in shape and are made of 16, 14, $\frac{1}{8}$-in. and $\frac{3}{16}$-in. gauge galvanised-iron sheeting.

In Manchester and other soft-water districts galvanised-iron tanks cannot be used, since the chemicals in the water would corrode the metal. Instead, light-gauge copper tanks are employed. For strength, these are cylindrical in shape, with domed top and concave base.

The hot-water installation in a small house is simple, and normally supplies three hot-water outlets: bath, bathroom basin and kitchen sink. Fig. 68 shows a simple layout of the small installation from either a back-fired or an

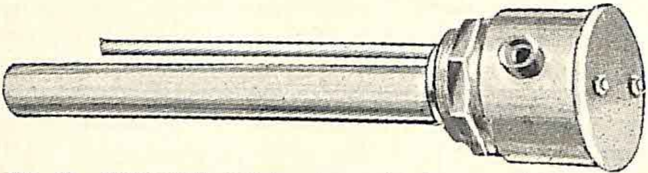


FIG. 69.—Removable core type immersion heater and thermostat.

independent boiler, with each outlet supplied from the expansion pipe.

Such an installation, for electrical conversion, requires little, if any, alteration to the pipework. Many small installations of this nature, while they may at first glance appear to be piped as in Fig. 67, upon investigation are found to have "short cuts", for reasons of economy in plumbing. The most usual "short cut" consists of "bleeding" the main flow-pipe from the boiler to supply the kitchen tap (Fig. 68). When the solid-fuel boiler is in operation this method has the advantage that small quantities of hot water can be drawn off direct from the boiler a few minutes after the fire is lighted, although the user has not the storage-tank capacity from which to draw.

When an electrical conversion is made where the flow-pipe has been bled, the user cannot satisfactorily draw off hot-water supplies. More often cold water only is drawn and flows from the cold-water tank via the boiler, the boiler, of course, not being in operation. This pipe (*XY*, Fig. 68*B*) should be removed and a new pipe (dotted lines) installed from the expansion pipe direct to the kitchen hot-water tap (Fig. 68*B*). Alternatively, a small storage heater $1\frac{1}{2}$–3 gallons

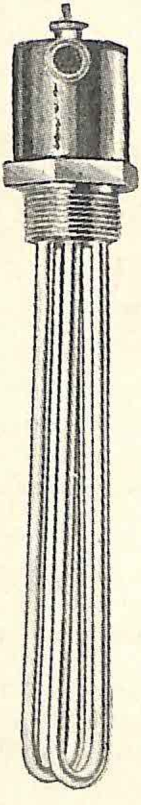


FIG. 70.—Cement filled sheathed element type immersion heater.

capacity, may be fitted over the kitchen sink in addition to the immersion heater in the tank. The main tank then supplies bath and wash-basin, and the small storage heater supplies the kitchen sink.

Existing water-heating systems in small modern houses are rarely difficult to convert, and pipework is necessary only in those cases where the kitchen tap is taken direct off the flow-pipe.

Secondary Circulation.—All secondary circulating systems, towel rails, hot-water radiators and such equipment must be cut off when electrical conversions are made. Radiators can be isolated with suitable valves for use only when the solid-fuel boiler is alight, and the same with towel-rails, although electric towel-rails often provide a better alternative to the use of the hot-water system for heating towel-rails.

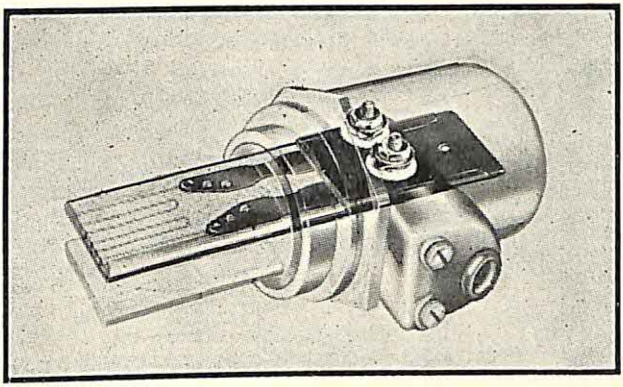


FIG. 71.—Flat-bladed-type immersion heater.

Converting Existing Systems.—Chief advantage of converting an existing hot-water system by using electric immersion heaters compared with the factory-produced storage heater, is the reduction in capital cost.

One 3-kW. immersion heater (Fig. 69), complete with thermostat, is quite suitable for the standard 20–30 gallon storage tank. A 20-gallon factory-produced self-contained storage water-heater costs about three times this amount.

Work is entailed in fixing and plumbing the immersion-heater type, particularly when the tank is lagged, but the initial cost of the converted system is still far below that of the self-contained type.

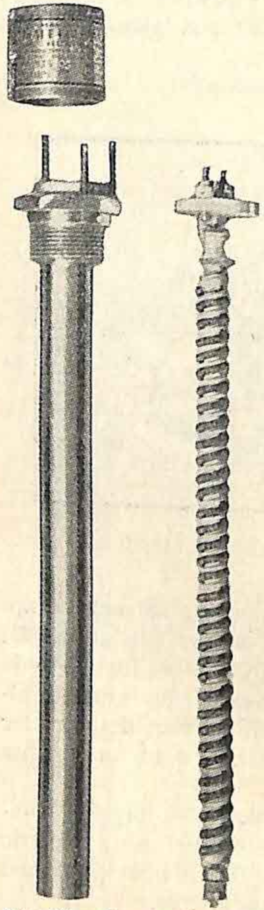


FIG. 72.—Removable core type immersion heater showing core removed.

Figs. 70–73 show various types of immersion heaters.

Inspecting the Existing Tank.—Before deciding to fit an immersion heater or circulator in an existing tank, a thorough inspection must be made to ascertain the condition of tank or cylinder, whether a secondary circulation is connected to the system, and whether any hot-water outlets are connected to the boiler flow and return pipes. If the tank is rusty inside, a new tank will be necessary, because disturbance caused by fitting the immersion heater would still further shorten its life.

Internal rusting is usually indicated by the appearance of white spots on the outside. Where it is not practicable to renew the tank, it is best to leave well alone, not to carry out an electrical conversion, and on no account to touch the white spots. The alternative then is to install self-contained electric water-heaters.

If a new hot-water storage tank is purchased, it is advisable to choose a good one of at least $\frac{1}{8}$-in. plate, which will last for many years.

The immersion heater should, of course, be fitted into a new tank before fixing the tank into position.

Before removing the inspection cover of an existing tank, whether it has been decided to fit an immersion heater or not, a new gasket should be purchased, because rarely can the old gasket be refitted. Such an inspection cannot be made of a copper cylindrical type of tank, for there is no inspection cover; but as a copper tank does not rust, it can usually be assumed that the tank wall is suitable for conversion.

Position of Immersion Heater.—Immersion heaters may be fitted either horizontally or vertically in the tank. Horizontal mounting is almost invariably used for rectangular-shaped galvanised tanks. In fact, unless the immersion heater is specially designed for vertical mounting, no attempt should be made to install it other than in a horizontal position.

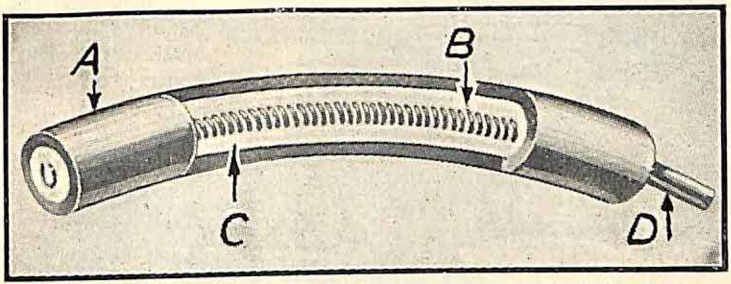


FIG. 73.—Sectional view of Metrovick Torribar sheathed element immersion heater. A, Protective sheath; B, Nickel-chrome element; C, Magnesium oxide insulators; D, Non-corrosive metal terminal.

If the whole of the contents of the tank are to be heated, the immersion heater must be fitted a few inches from the bottom, since the water below the heater remains at the incoming temperature, e.g., approximately 50 deg. Fahr., and will not be heated. Where an excessively large tank is installed, the capacity of which exceeds normal requirements, it is not always economical to heat the whole contents, in which case the element should be fitted higher, its actual height depending on the maximum amount of hot water required.

The position of the thermostat also is important. Where this is incorporated in the immersion-heater flange there is, of course, no alternative position. Otherwise, the thermostat should be mounted about 6 ins. from the heater in the same horizontal plane. Below this position it will not "switch off" because the temperature will not reach the predetermined figure at which the thermostat is set. Above this level it will operate too early, for the contents heat up from the top of the tank downwards. The thermostat must not be placed in the hot-water stream immediately above the heater.

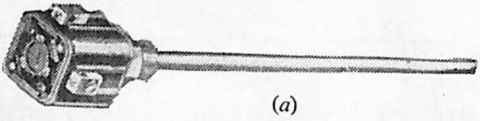
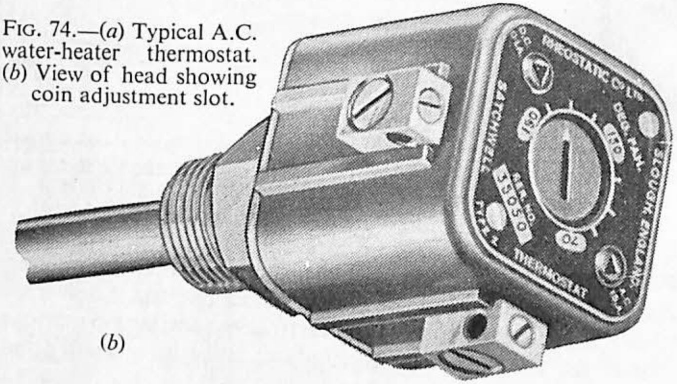

(*a*)

FIG. 74.—(*a*) Typical A.C. water-heater thermostat. (*b*) View of head showing coin adjustment slot.



(*b*)

The circulator type of immersion heater must, of course, be fitted in the top of the tank. This should be placed in the most convenient position, and where no inspection cover is available care must be taken to ensure that the position chosen will not be fouled by pipes. Normally a copper cylinder is free of internal piping.

Where circulators cannot be fitted into a cylinder, due to lack of head room, which must be sufficient to allow the heater to be placed in or withdrawn, circulators for external fitting may be used.

Principle of the Thermostat.—The thermostat performs two functions: To measure the temperature of the water and to control the current to the heater. This is achieved by a sensitive element which operates a switch. Normal position of the switch in the water-heating types of thermostats is "On". Therefore, current flows through the heater immediately it is switched on from an external source.

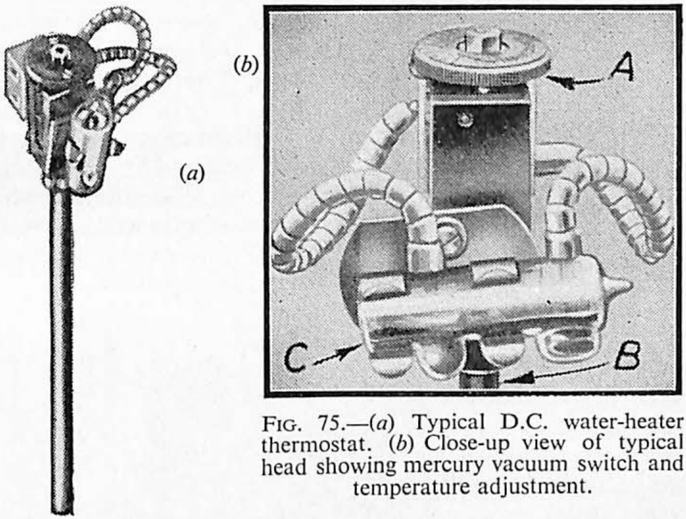


FIG. 75.—(*a*) Typical D.C. water-heater thermostat. (*b*) Close-up view of typical head showing mercury vacuum switch and temperature adjustment.

The sensitive element of the thermostat normally employed for water heating consists of a bi-metal rod which, on expanding, opens the switch contacts which are held together by a spring. To give a range of predetermined temperatures from 90 deg. Fahr. to 200 deg. Fahr., an adjustment is incorporated in the switch portion or head of the thermostat. Adjustment is made with a coin or similar "tool" (see Fig. 74).

Although a thermostat will break a circuit at its predetermined setting—e.g., 160 deg. Fahr.—it will not remake the circuit until the temperature of the water drops to

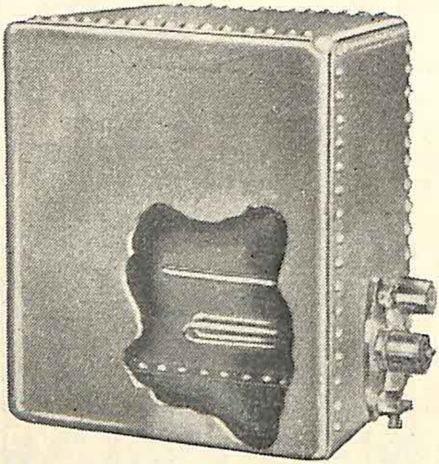


FIG. 76.—Special three-way flange fitted to a tank.

150 deg. Fahr. This characteristic is termed its differential, and is the difference between cutting-out and cutting-in temperatures. Differential varies between different types of thermostats, but for water-heaters is usually about 10 deg. Fahr.

When setting the thermostat, consideration must be given to the "hardness" of the water. The "degree" of hardness can be obtained from the local water authority. In soft-water districts, where little or no scale is formed, thermostats may be pre-set up to 190 deg. Fahr., which gives the maximum effective storage capacity, but in hard-water districts 170 deg. Fahr. is the recommended maximum, since at this temperature most scale begins to form. In very hard

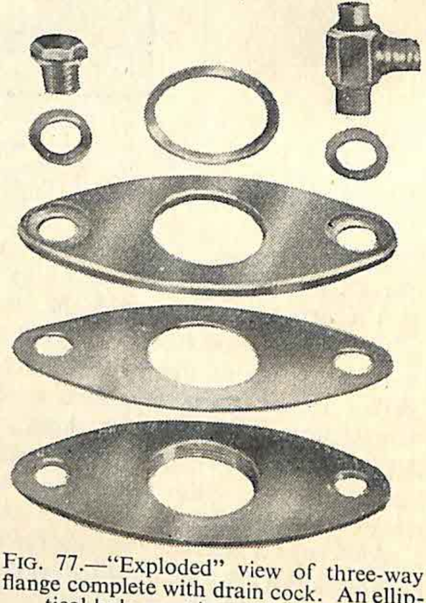


FIG. 77.—"Exploded" view of three-way flange complete with drain cock. An elliptical hole must be cut in the tank.

water districts 160 deg. Fahr. is the limit unless the heater is specially designed for hard-water districts.

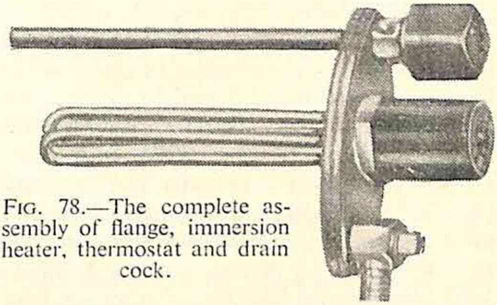


FIG. 78.—The complete assembly of flange, immersion heater, thermostat and drain cock.

Local electricity supply authorities and municipal authorities often require a maximum setting of 140 deg. Fahr. where the heater is their property.

When purchasing a thermostat it is important to remember that a thermostat designed for A.C. (alternating current) will not operate on D.C. Most A.C. thermostats incorporate micro-gap switches, but if used on D.C., arcing will occur and the switch will burn out and possibly weld the two contacts together. If the current were not switched off owing to the thermostat not operating, due to welded contacts, damage from overheating of the water would occur.

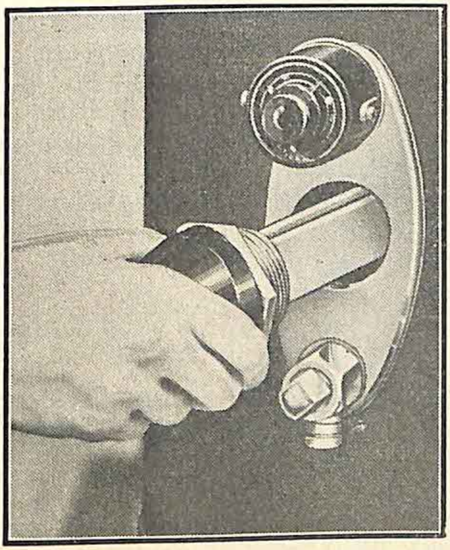


FIG. 79.—Screwing the immersion heater into the flange.

D.C. thermostats usually operate on the mercury vacuum switch principle where no arc can occur (Fig. 75). This switch, which is more expensive than A.C., is universal and can be used on both D.C. and A.C. A.C. thermostats having micro-gap switches can be made to operate on D.C. by placing a suitable condenser across their terminals, but this method is not completely satisfactory because the condenser may break down and the thermostat burn out.

Fitting a Heater.—Where an inspection cover is available this should be removed by unscrewing each bolt, after first marking both tank and cover to ensure that it is replaced in exactly the same position. Having decided upon the position of the heater and thermostat, a template is cut and the tank accurately marked.

A special tank-cutter should be used, and saves a lot of time and trouble. This consists of a special tool having a twist drill for making a "pilot" hole, followed by a tank-cutter for the final hole.

The flange is then bolted to the tank—brass bolts only should be used to prevent corrosion—and the immersion heater and thermostat screwed in, using a small quantity of jointing material. A new gasket should be obtained for the inspection cover and a mixture of red lead and white lead or special jointing paste used to complete the joint.

Special flanges, made in various forms, are available to overcome the disadvantages of removing the inspection cover. Here a special hole is cut, the flange is secured to the tank and the work is now complete, as shown in Fig. 76. Figs. 77–79 show the flanges.

XIII

CIRCULATORS FOR ELECTRIC WATER HEATING

SINGLE-HOLE fixing is widely adopted for copper cylinders (Fig. 80), some types being made for tinning and soldering to the copper cylinder wall. Sometimes it is necessary to use a template, and this is often provided by the manufacturers.

Where drilling the tank is particularly difficult or impossible and the tank capacity is larger than necessary, it is often possible to fix the immersion heater in the inspection cover. To do this, the cover is removed in the normal way, the hole drilled and the

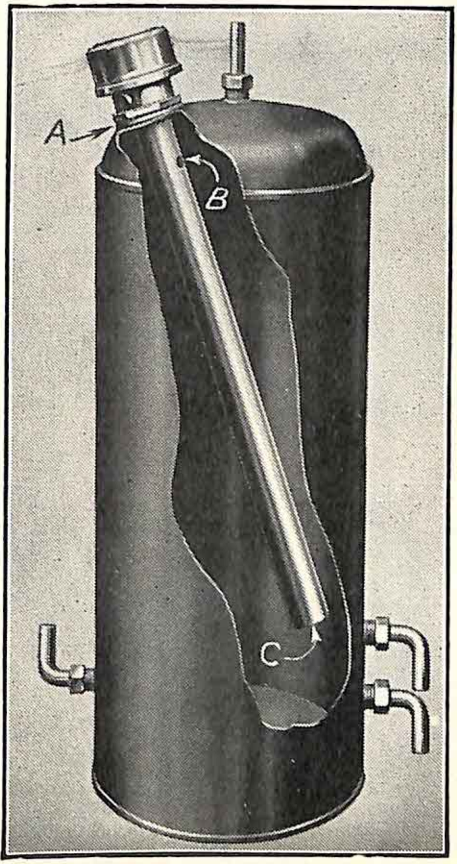


FIG. 80. — Cut-away cylinder showing the position of the circulator type heater. Thermostat is enclosed in draught tube. Note the single hole fixing of heater flange in the top of the cylinder.

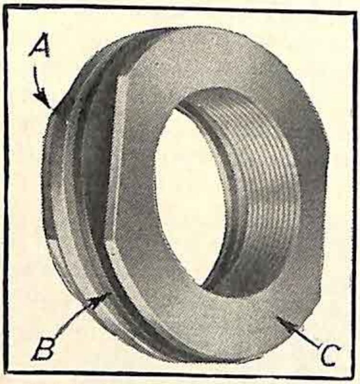


FIG. 81.—Non-soldering Essex type flange.

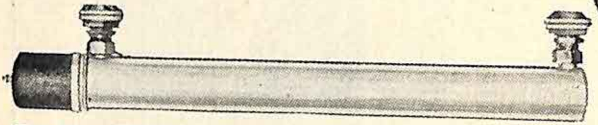


FIG. 84.—Circulator for externally fitting to the water-heater.

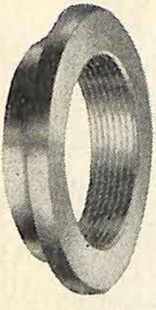


FIG. 82.—"Sweated" ring type flange.

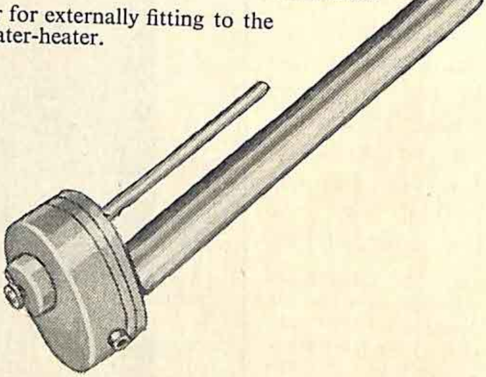


FIG. 83.—Circulator for horizontal fixing, which can be used in cylinders or rectangular tanks. This type of heater is shown fitted in a cylindrical tank in Fig. 89.

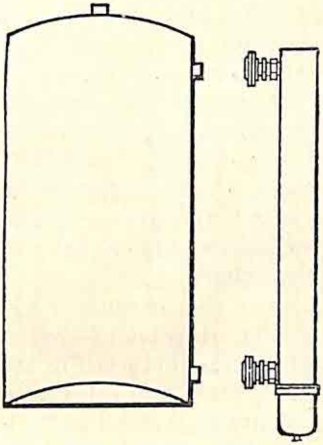


FIG. 85.—Two holes bored in the tank into which flanges are inserted or "sweated" and the heater screwed on.

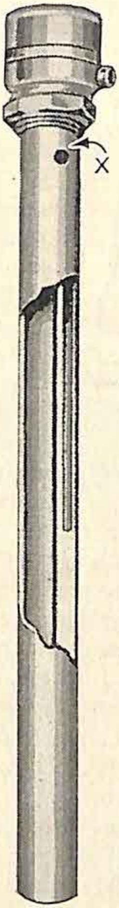


FIG. 86.—(*Right*) A Standard circulator. X, Vent Hole.

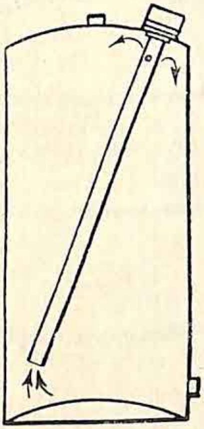


FIG. 88. Method of installation.

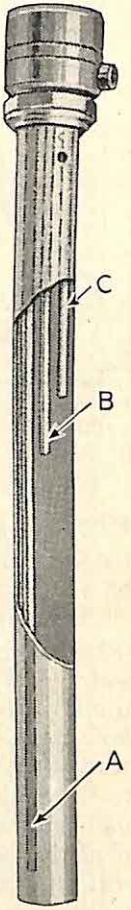


FIG. 87.—Circulator with booster heater comprising an additional element to give a high loading and therefore quicker heating.
A, Booster Heater; B, Thermostat; C, Constant Heater.

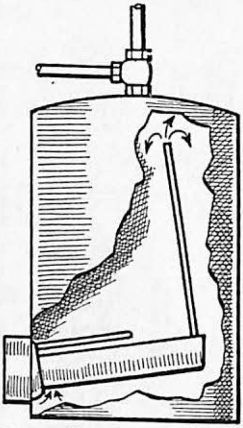


FIG. 89.—Showing the method of installation of the heater given in Fig. 83.

heater screwed home. Inspection of the element is then a simple operation. Before adopting this method, care must be taken to ensure that the tank contents—viz., water—above the element will meet the demands of the household.

Circulators.—These are fitted in the existing storage tank and enable small quantities of hot water to be drawn off soon after switching on.

They consist of an immersion-heater element surrounded by an outer sheath or draught tube (Fig. 80). Figs. 81 and 82 show two other types of flange. Water in contact with the element circulates upwards inside the draught tube and passes through a comparatively small hole at the top. This is stored in the top of the tank and can be drawn off at once by the user.

Circulators should, however, only be used in soft-water, not hard-water districts, as in the latter the vent hole quickly becomes fouled with scale. In fact, circulators which can only be mounted vertically are particularly adaptable in the soft-water districts, for it is in these areas where the cylindrical copper tanks are largely fitted. These tanks have a height much greater than their diameter. Horizontal immersion heaters are usually too long and cannot be

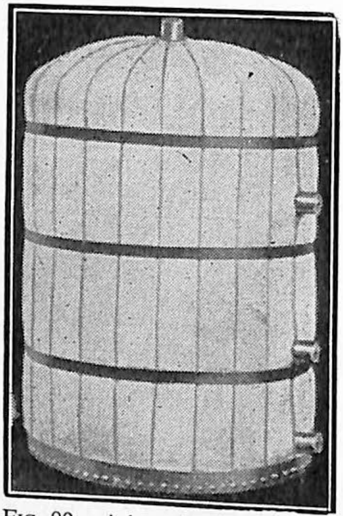
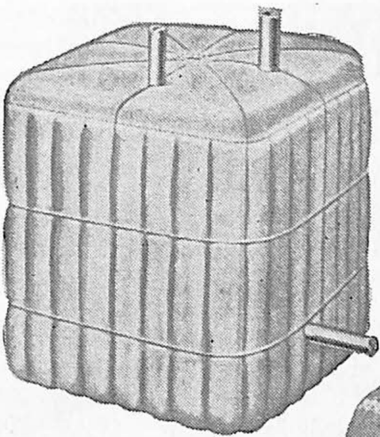
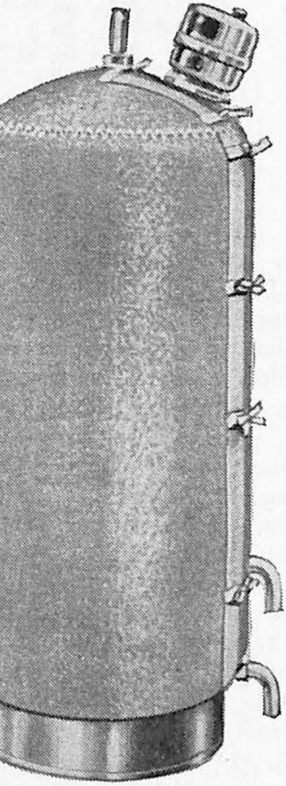


FIG. 90.—A heat insulated jacket for tank lagging.

accommodated, but circulators, due to their length, will usually extend almost to the base of the tank, but rarely can be fitted in rectangular galvanised tanks, which are not, of course, installed in soft-water districts.





FIGS. 91 and 92.—Further examples of jackets which can be wrapped round rectangular and cylindrical tanks.

Other Types of Circulator.—Where there is little head room above a cylinder and it is not possible to install a conventional type of circulator which is fitted vertically in the top of the cylinder, two other types are available. These are: side-entry circulators (Fig. 83) and external circulators (Fig. 84).

The side-entry circulator consists of an immersion heater fitted horizontally in the side of the tank and a vertical extension draught tube which passes through the body of the tank and terminates near the top. This has an open outlet through which the hot water

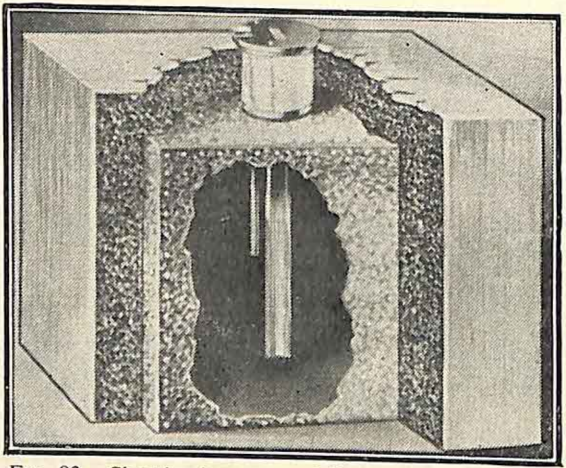


FIG. 93.—Showing how a wood framework can be built around a tank and filled with cork granules.

circulates. As with the conventional type, small quantities of hot water can be drawn off shortly after switching on the heater. A thermostat is usually incorporated. These, like all circulators, should not be installed in hard-water districts owing to the scale which is likely to form in the small draught-tube outlet.

External Circulator.—These are fitted externally to the side of the tank or cylinder. Two holes are bored in the tank, into which flanges are inserted or "sweated" and the heater is screwed on (Fig. 85). If the cylinder is fitted with boiler flow and return connections and these are not being used, the circulator can be fitted to them. Figs. 86 and 87 depict other types of circulators, and Figs. 88 and 89 show the methods of installation.

Two-element Conversion.—This system has become a most popular method of control. Two immersion heaters are installed in the tank, one at the bottom with a loading of 2–3 kW. and one of 1 kW. near the top of the tank. These can be controlled by separate thermostats, though hand control may be used, but is, of course, less satisfactory.

For all normal use the smaller heater at the top may be used. Small quantities of water for washing and washing-up can be drawn off, but when a bath is required the lower heater is also brought into operation, and the whole contents are heated. The chief advantage of this method is the saving in running costs, since, as only part of the tank contents are normally heated, losses are therefore reduced to a minimum. It is necessary only to lag the top portion.

Lagging.—A converted electric hot-water tank should be adequately lagged to prevent undue loss of heat and unnecessary consumption of electricity.

Lagging is generally carried out with granulated cork.

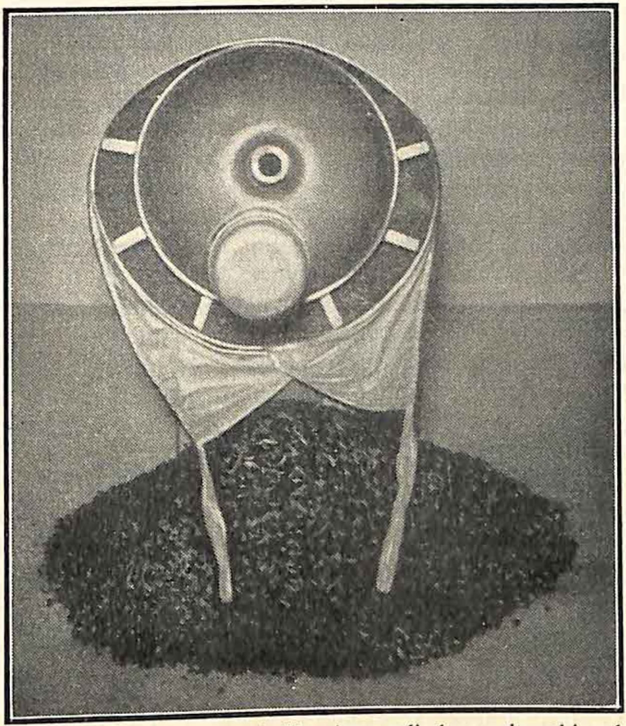


FIG. 94.—Another method of lagging a cylinder can be achieved with an old blanket or corrugated cardboard using several layers under a canvas cover.

This form is one of the cheapest and most effective methods of lagging a rectangular tank. Special prefabricated heat-insulated jackets are, however, obtainable for both rectangular and cylindrical type tanks, and are wrapped round as a jacket (Figs. 90–92). Granulated cork can, of course, be used for cylindrical tanks (Fig. 93), while an effective job can be achieved with an old blanket or corrugated cardboard using several layers over which a canvas cover is sewn (Fig. 94).

Before applying granulated cork to a rectangular tank, a frame of matchboard should be built, leaving a space of at least 2 ins. between the tank and the woodwork for pouring in the cork. This is then rammed in firmly and evenly (Fig. 93), and an effective heat insulator is thus made.

Heat losses from a lagged tank (3 ins. of granulated cork), where the temperature of the water is 180 deg. Fahr., are approximately 4 watts per sq. ft. of surface area. Heat losses, on the other hand, from an unlagged tank, where the water temperature is 180 deg. Fahr., are between 36 and 72 watts per sq. ft.

Immersion Heater.—Immersion heaters are made in various electrical loadings from 500 watts up to 6 kW. (6,000 W.). Size of heater to install depends on: capacity of tank, whether thermostatically or hand controlled, and the time which is to be allowed to heat up the tank's capacity from cold. Maximum loading in an additional case also depends on the electricity supply authority's regulations. Some authorities require a low loading.

Calculating Optimum Size of Element.—The average hot-water tank has a capacity of between 20 and 30 gallons. One 2-kW. heater where a thermostat is incorporated is usually sufficient, but with hand control a 3- or 4-kW. heater should be used.

XIV

TANK CAPACITIES OF WATER-HEATERS

HEAT and Electricity.—British Thermal Unit (B.Th.U.) is the heat required to raise 1 lb. of water through 1 deg. Fahr. This is equal to 0·293 watt-hour, which is a little over $\frac{1}{4}$ of 1 watt-hour.

1 watt = 3·415 B.Th.U. per hour.

1 kilowatt hour (kWh.) or 1 unit is equal to 3,415 B.Th.U.s.

Assuming the temperature of the incoming cold water is 54 deg. Fahr., and it is required to raise 1 gallon to 180 deg. Fahr. or through 126 deg. Fahr. at 100 per cent. efficiency, electricity consumed would be 0·37 kWh., or $0{\cdot}37 \times 20 =$ 7·4 kWh for 20 gallons.

At 80 per cent. efficiency, consumption would be 0·46 kWh. and 4·6 kW. for 1 and 10 gallons respectively.

To ascertain the electricity consumed for any set of conditions, the formula used is:

Units consumed—

$$\frac{\text{Galls. of water} \times \text{temp. rise in deg. Fahr.} \times 10 \times 100}{3{,}415 \times \text{efficiency per cent.}}$$

With 20 gallons of water, 126 deg. Fahr. temperature rise and an efficiency of 80 per cent., we get

$$\frac{20 \times 126 \times 10 \times 100}{3{,}415 \times 80} = 9{\cdot}2, \text{ or 9 units approx.}$$

To estimate the loading of an immersion heater, in kW., to heat water in a given time, the formula used is:

$$\frac{\text{Temp. rise deg. Fahr.} \times \text{galls capacity} \times 10 \times 100}{3{,}415 \times \text{hours} \times \text{efficiency per cent.}}$$

Assuming temperature rise is 126 deg. Fahr., tank capacity 20 gallons, heater efficiency 80 per cent., and the given time or recovery period is to be 4 hours, we get:

$$\frac{20 \times 126 \times 10 \times 100}{3{,}415 \times 4 \times 80} = 2{\cdot}3 \text{ kW.}$$

This 2·3 kW. switched on for 4 hours consumes 9·2 kWh.

As no 2·3-kW. heater is made, the choice lies between 2 kW. and 3 kW. If hand controlled, the larger size should be adopted, but manufacturers install a 2-kW. heater in self-contained lagged automatic storage heaters of 20 gallon capacity.

Where it is necessary to ascertain the time it would take to heat a quantity of water with a given loading the following formula is used:

$$\frac{\text{Temp. rise in deg. Fahr.} \times 10 \times 100}{3{,}415 \text{ loading in kW.} \times \text{efficiency}}$$

Assuming a temperature rise of 126 deg. Fahr., capacity of tank 25 gallons, immersion heater of 3·0 kW. loading and an overall efficiency of 80 per cent.

Time taken in hours—

$$\frac{126 \times 25 \times 10 \times 100}{3{,}415 \times 3 \times 80} = 4 \text{ hours approx.}$$

If the temperature rise is known, the heater loading, overall efficiency and the time taken to raise the water to that temperature, gallons heated can be ascertained from the formula:

$$\frac{\text{kW.} \times 3{,}415 \times \text{hours} \times \text{efficiency per cent.}}{\text{Temp. rise in deg. Fahr.} \times 10 \times 100}$$

Using the figure 3 kW., 4 hours, 80 per cent. efficiency, 126 deg. rise in temperature, we get:

$$\frac{3 \times 3{,}415 \times 4 \times 80}{126 \times 10 \times 100} = 25 \text{ gallons.}$$

Overall efficiency of heater is obtained thus:

$$\frac{\text{Temp. rise in deg. Fahr.} \times \text{galls.} \times 10 \times 100}{3{,}415 \times \text{loading in kW.} \times \text{time in hours}}$$

If temperature rise is 100 deg. Fahr., capacity 20 gallons of water, loading is 3 kW. and time taken $2\frac{1}{2}$ hours:

$$\text{Efficiency} = \frac{100 \times 20 \times 10 \times 100}{3{,}415 \times 3 \times 2{\cdot}5} = 78 \text{ per cent.}$$

These figures are representative of normal operating conditions, and therefore an adequately heat-insulated tank has an approximate efficiency of 90–95 per cent. and the approximate efficiency of a non-insulated tank 80–85 per cent.

Where only rough calculations are needed, the following will give approximate requirements within a reasonable degree of accuracy.

Electricity Consumption.—One unit of electricity (kWh.) will raise: 2 gallons of water at average cold mains temperature (52 deg. Fahr.) to boiling point (212 deg. Fahr.); 3 gallons to 150 deg. Fahr. and $5\frac{1}{2}$ gallons to 100 deg. Fahr.

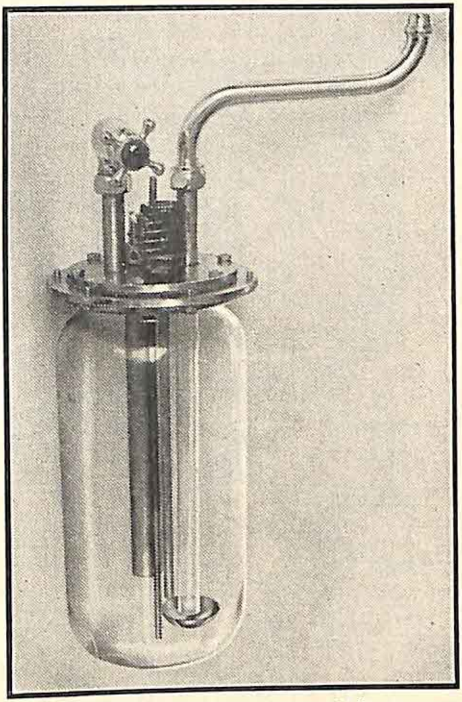


FIG. 95.—Pyrex container removed from outer casing shows the operation of the displacement type water-heater. The mushroom head of the anti-drip device can be clearly seen.

Approximate Capacity of Tank.—Approximate capacity, in gallons, of rectangular and cylindrical tank can be found from the formulae:

Rectangular:

$$\frac{\text{Length} \times \text{breadth} \times \text{height}}{280} = \text{gallons}$$

All dimensions in inches.

Example: $\frac{18 \text{ in.} \times 18 \text{ in.} \times 20 \text{ in.}}{280} = 23$ gallons approx.

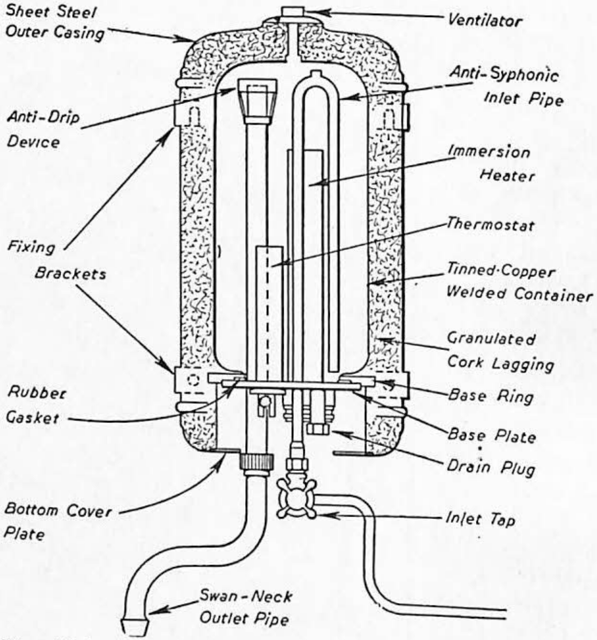


FIG. 96.—(*a*) A displacement type, single point, $1\frac{1}{2}$ gallon water-heater, and method of connecting it to the cold water mains. Compression fittings of the Kontite type are used, which require no plumbing or soldering.

Cylindrical:

$$\frac{\text{Diameter} \times \text{diameter} \times \text{height}}{350} = \text{gallons}$$

Example: $\frac{15 \text{ in.} \times 15 \text{ in.} \times 36 \text{ in.}}{350} = 23$ gallons approx.

Water is normally stored in the tank at a higher temperature than that at which it is used. By mixing with cold water, the right quantity at the right temperature is obtained. For instance, temperature of water for washing-up should not be more than scalding temperature, which is 120 deg. Fahr., and for a bath the average temperature is 105 deg. The amount of water required for a medium-sized bath is about 22 gallons; 10 gallons at 180 deg., mixed with 12 gallons of 50 deg. Fahr.

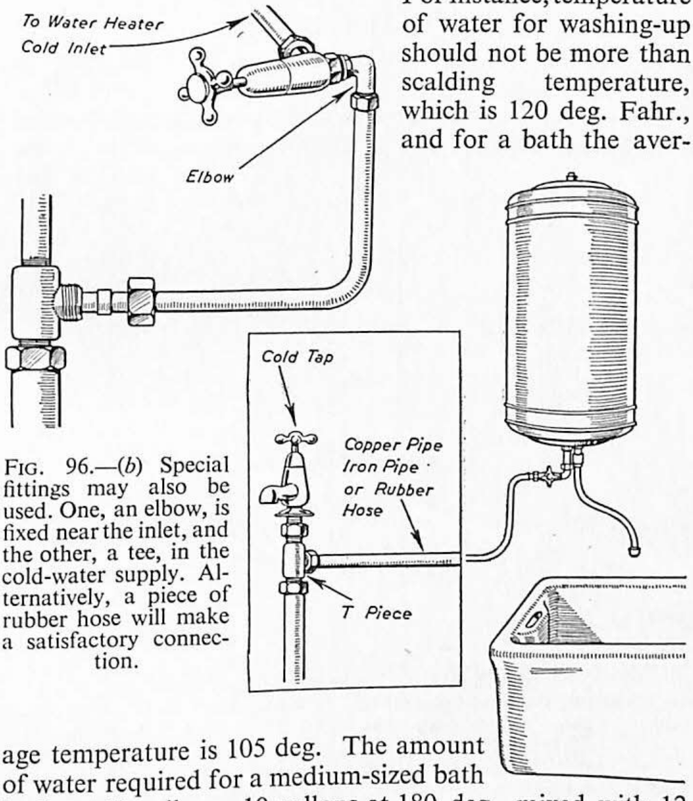


FIG. 96.—(*b*) Special fittings may also be used. One, an elbow, is fixed near the inlet, and the other, a tee, in the cold-water supply. Alternatively, a piece of rubber hose will make a satisfactory connection.

The formula for ascertaining the resultant temperature is:
Resultant temperature=

$$\frac{\text{Galls. hot} \times \text{temp. hot} - \text{galls. cold} \times \text{temp. cold}}{\text{Total gallons}}$$

$$= \frac{10 \times 180 \text{ deg.} - 12 \times 50 \text{ deg.}}{22} = 109 \text{ deg. Fahr.}$$

Assuming that the temperature of the hot water is 160 deg. Fahr., and this figure should not be exceeded in hard water-districts, or scale will form and the elements' and heater's effective storage reduced:

$$\frac{160 \times 10 - 12 \times 50}{22} = 100 \text{ deg. Fahr. resultant temp.}$$

Where in the former case two good baths can be obtained in quick succession from a 20-gallon water-heater, in the latter less cold water must be used to obtain the required temperature. Alternatively, some little time must elapse between the two baths. In practice, where the loading of the heater is 3 kW. or higher, sufficient recovery is made by the time the first bath has been taken. In effect, therefore, two consecutive baths are possible from a 20-gallon heater.

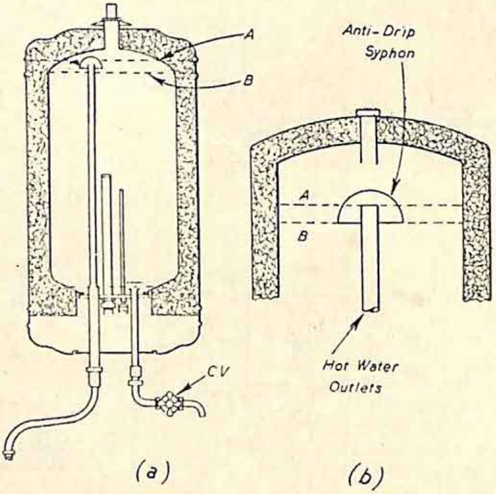


FIG. 97.—Anti-drip device on displacement type water-heater. Upon the closing of the control valve CV, water level is at "A". Water still runs up outlet by syphonic action and the level is reduced to "B". Water, upon being heated again, can expand to "A" before dripping occurs, but this rarely happens.

Self-contained Water-heaters.—These consist of water containers, usually made of sheet copper, with lapped or welded joints and tinned inside. Smallest sizes, 1½ gallons, sometimes have heat-resisting glass containers of the Pyrex type (Fig. 95), and are suitable for culinary purposes where the water supply is taken direct from the mains. Monel, a special non-corroding alloy, is also used for containers.

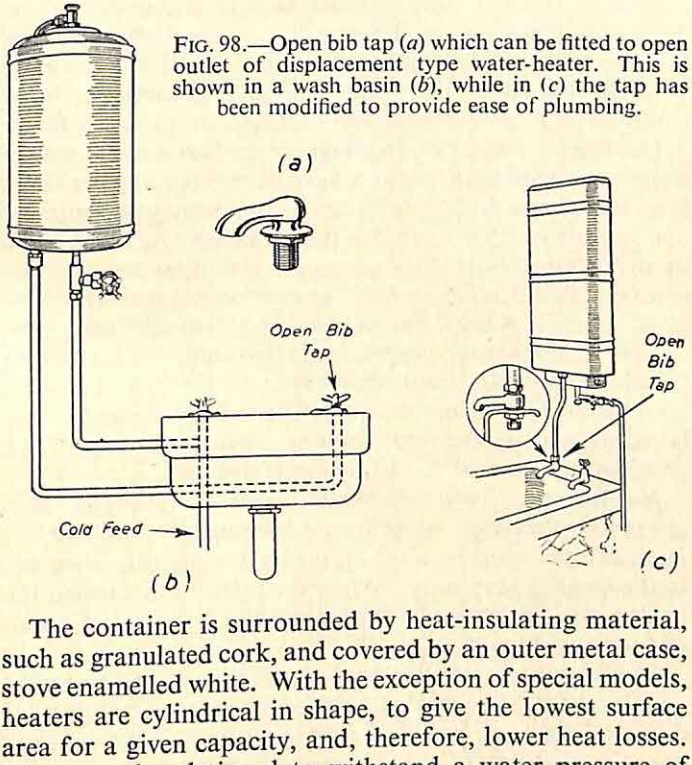


FIG. 98.—Open bib tap (*a*) which can be fitted to open outlet of displacement type water-heater. This is shown in a wash basin (*b*), while in (*c*) the tap has been modified to provide ease of plumbing.

The container is surrounded by heat-insulating material, such as granulated cork, and covered by an outer metal case, stove enamelled white. With the exception of special models, heaters are cylindrical in shape, to give the lowest surface area for a given capacity, and, therefore, lower heat losses. They are also designed to withstand a water pressure of 50 lb. per sq. in., which is equivalent to a 115 ft. head of water, rarely met, of course, in domestic premises.

Inlet pipe is in the base of the container, and has a baffle, usually of mushroom shape, fitted over the open end to prevent incoming cold water mixing with the hot, and enables from 75–85 per cent. of the heater contents to be drawn off without any noticeable fall in temperature.

The outlet pipe is also at the bottom of the heater, though in some heaters, as will be seen later, a second outlet is provided at the top. This arrangement of two outlets simplifies plumbing where outlet taps are to be fed above and below the heater.

Heating element and thermostat are mounted on an apparatus plate mounted vertically on the bottom of the water container in the smallest heaters, which are fixed on the wall; and horizontally inside of the large heaters, which, owing to their weight when full of water, stand on the floor.

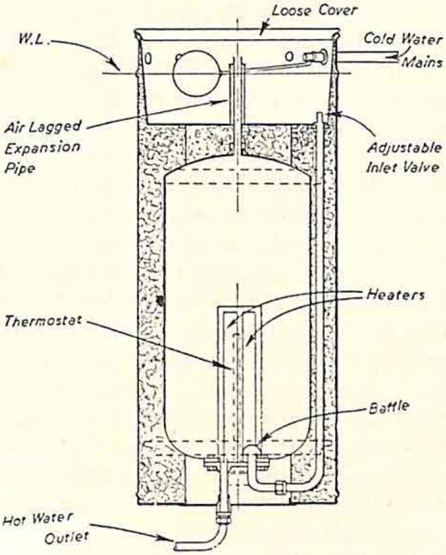
Loadings.—Electrical loadings of self-contained water-heaters are standardised, and have been fixed as a result of long experience by manufacturers and supply authorities, and range from 500 watts for the 1½ gallon and 6·0 kW. or more for the 100-gallon size. These give a recuperation or recovery period of about four hours (except for the smallest sizes, where it is less), but as they are thermostatically controlled and are well lagged, little advantage is gained in switching them off except when not in use for long periods of about four days or more. Therefore, recovery, or the time taken to heat up the total contents, is not very important, provided the correct size of heater is installed.

Non-pressure Type of Water-heater.—This type, also termed displacement water-heater because the supply of hot water is controlled by a tap in the cold-water inlet, is made in the smaller sizes only. When the inlet tap is opened the cold water displaces the hot by an overflow leading to an open spout (Fig. 96).

The three most popular displacement types are 1½-, 3- and 5-gallon sizes, the smallest being most extensively used for domestic purposes and ideal for fixing over the kitchen sink, over the wash-basin, or any position where small quantities of hot water are required at frequent intervals.

One outlet only can be supplied from the displacement type, it being essential that the outlet is always open, or pressure would build up in the heater and damage would result.

Installation is simple. The existing cold tap is removed, a tee-piece inserted and the tap replaced. A few feet of piping



is then installed between heater and tee-piece, and no other plumbing is necessary.

Special fittings may also be used which consist of two compression pieces. One, an elbow, is fixed near the inlet, and the other, a tee, in the cold-water supply. A short piece of copper piping is installed and the unions are tightened (Fig. 96). These, known as the Kontite fittings, require no plumbing or soldering. Alternatively, a piece of rubber hose pipe may be used, but the copper pipe is more satisfactory.

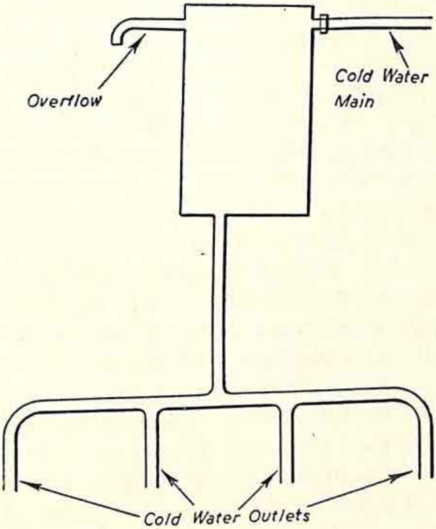


FIG. 99. A cistern type heater, which is a self-contained water-heater system as shown above. Usually the cold water mains may be connected direct to inlet as shown. Closed (tap) outlets may be run from the outlet and therefore minimum plumbing is required.

Average use of hot water from a $1\frac{1}{2}$-gallon heater in the kitchen is 6 gallons per day at 180 deg. Fahr., which gives the user 10 gallons of really hot water for a daily consumption of 2·5 kWh. or units per day. This heater need never be switched off, and the standby losses are only 4 units per week. In view of the convenience of constant hot water, it is therefore worthwhile leaving the water-heater constantly in circuit for such a small weekly loss.

Displacement, or non-pressure type water-heaters, are made in capacities up to 30 gallons. The 12- and 15-gallon heaters are suitable where two baths are not taken in quick succession, and the 20- and 30-gallon heaters for larger premises or where two consecutive baths are frequently required.

Although only one outlet is allowed to be taken from displacement heaters, two points, such as bath and wash-basin, can be served by one heater by fixing it on the wall between the bath and the basin and arranging the swivel spout accordingly.

Anti-drip Arrangement.—Water expands approximately 4 per cent. in volume when heated through a temperature rise of 150 deg., i.e., from 40 deg. Fahr. to 190 deg. Fahr., which is approximately the rise in temperature in the normal installation.

As the displacement-type water-heater has an open outlet, dripping, due to expansion of the water on heating, would occur. Self-contained storage heaters are therefore fitted with an anti-drip device, the most common being in the form of a syphonic trap formed at the top end of the outlet pipe. When the cold-water inlet valve is shut off, water continues to run for a few seconds, as the level of water in the container drops slightly to allow for this expansion. When the tap is turned on again there is a delay of a few seconds before the hot water flows. The user soon becomes used to this characteristic, and operates the tap accordingly (Fig. 97).

Where it is not convenient to install the water-heater over the sink or bath, a length of pipe may be run to the tap position and, as it must have an open outlet, this tap can be replaced by an open bib tap (Fig. 98).

Cistern-type Water-heaters.—These are complete, compact electric water-heating systems in themselves, and comprise: storage-water container, immersion heater and thermostat-and-ball-valve system contained in one outer casing. Provision is made for cold-water inlet and overflow, and hot-water outlet (Fig. 99).

Standard capacities (hot-water storage) range from 5 gallons up to 100 gallons with standard loadings. These can be connected direct to the cold-water mains supply, and any number of hot-water outlet points may be supplied, but since they are gravity fed, no outlet must be situated at a higher level than the storage tank.

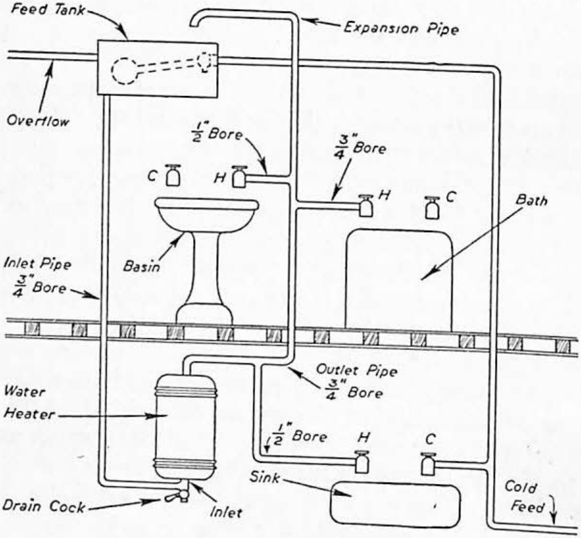
Cistern-type water-heaters operate on either of two systems: (*a*) constant volume and variable temperature where the cold water is drawn off and the storage container is always full of water, and (*b*) the constant-temperature variable-volume system, where hot water can be drawn off at a greater rate than the cold water enters the chamber.

Advantage of method (*b*) is that all the hot water can be drawn off without drop in temperature, since incoming cold water is so slow that it does not mix and cause cooling. This is achieved by the incorporation of a restricted cold-water feed between ball-valve cistern and hot-water container. This adjustable water-feed valve is shown in Fig. 99.

Where water-supply authorities do not allow this type of water-heater to be connected direct to the main supply, it should be connected to a downward feed from the house cistern.

In the heater illustrated in Fig. 99 it will be seen that the immersion heater and thermostat are enclosed in a cylinder. This is always full of water, and is a precaution against burning out the heater when the water container is drained, either through failure of water supplies or when the constant-temperature variable-volume system is used. The thermostat then operates when the small quantity of water reaches the pre-determined temperature.

Pressure-type Water-heaters.—This type of storage water-heater is fundamentally the same as the hot-water storage tank in the normal domestic hot-water system after conversion to electric, but it is factory produced. Capacities range from 3 gallons with an electrical loading of 1 kW. up to 100 gallons with a loading of 6 kW. or more. Special models are also made for industrial and commercial application with higher loading capacities. Small sizes, 3–30 gallons, are arranged for wall mounting, and above this capacity are floor-standing.



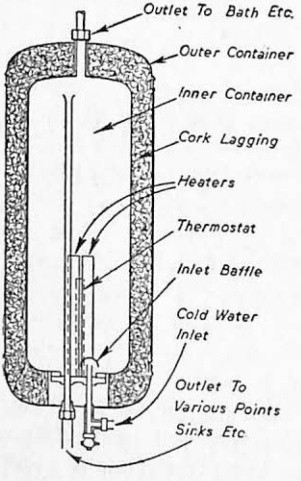


FIG. 100.—Pressure-type water-heater for wall fixing. Outlets may be taken either from the top or bottom. This heater must be fed from a ball-valve type of cold water cistern. Outlets are of the closed (tap) type. Floor standing models operate similarly, but the immersion heater is installed horizontally to allow for inspection. Piping arrangements are shown on the diagram on the left.

Pressure-type water-heaters are made and designed to operate in a similar manner to the displacement types, but instead of having an open outlet, the system operates under a pressure, with the control points on the hot-water outlets instead of the cold-water inlets.

Heaters of this type should not be connected to the mains water supply, but from a low-pressure tank supply. Pressure of the hot-water system will therefore depend on the height of the cold-water feed cistern above the storage heater, as in the normal solid-fuel system. The cold-water inlet is situated at the base of the heater, and the hot-water outlet at the top, to which is connected the expansion pipe from which the hot-water outlets are run (Fig. 100). Any number of hot-water outlets may be run from the system.

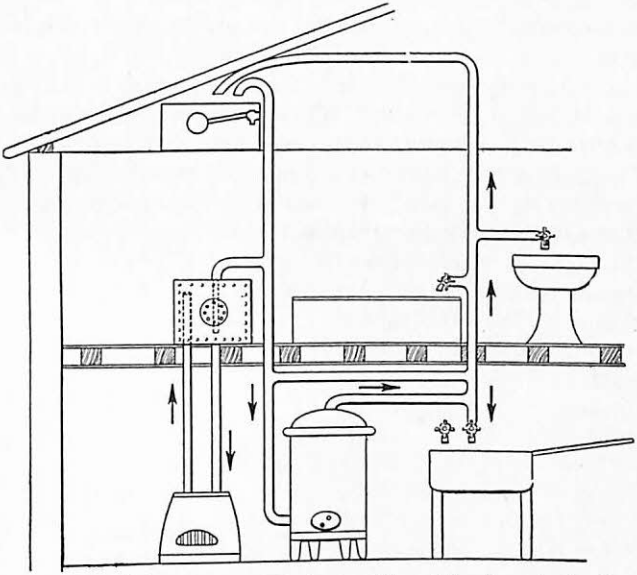


FIG. 101.—Utilising a pressure type self-contained water-heater in conjunction with a solid fuel "boiler" system. Since the electric heater is fed from the outlet of the hot water storage tank, when the fire is lighted the electric heater may be used as a booster heater. Total storage is therefore increased.

Outlets can also be taken from below this heater, as indicated.

Pressure-type water-heaters may be used either as the sole source of hot-water supply or in conjunction with the solid-fuel system (Fig. 101). When the latter method is adopted, not only does it act as a booster heater when the solid-fuel boiler is in operation, but serves as additional storage capacity, which greatly adds to the utility of the existing system.

Hot-water outlets may be situated above or below the heater, but not, of course, above the cold-water cistern, which is usually situated in the loft.

The expansion pipe, which extends to a position above the cold-water storage tank, must always have an open end, or undue pressure will build up in the water container as the volume of the water expands. Also, this pipe should rise vertically without bends, to provide an outlet with minimum resistance. From this pipe the horizontal-hot-water service pipes are run. Therefore the size of the expansion pipe should be large enough to provide maximum flow to all positions.

XV

ELECTRIC HEATER PLUMBING

WATER-HEATER manufacturers, aware of the need for a self-contained electric water-heater in the small home, have developed what is known as the U.D.B., or Under the Draining-Board heater. It has been developed to meet the demand for a trouble-free hot-water service for the small house and cottage, especially where space is restricted.

It is an entirely automatic water-heater, having 20 gallons capacity. Constructed similar to the pressure-type water-heater described earlier, it consists of an inner water-contaner (18-gauge copper) with copper moulded seams, but tinned inside and outside.

An outer steel casing surrounds the container with a lagging space, between which is packed granulated cork to a thickness of 2 in. all round. At the top the lagging is 3 in.

Connections to the water-heating system are made by means of two ¾-in. unions. The cold-water inlet connection is situated in the side of the container near the bottom, while the hot-water outlet is brought out of the side near the top (Fig. 102). A drain-cock is provided near the cold-water inlet at the bottom.

When used as an independent water-heating system, connections are made as in Fig. 103, a cold-water storage tank being essential. This type of heater can, however, be used in conjunction with an existing solid-fuel boiler, when the connections are made as in Fig. 104. Most interesting feature of this type of water-heater is that two independent elements are provided, each with a separate thermostat, and are independently thermostatically controlled. The heater is therefore actually two heaters in one.

For ordinary everyday use, to supply hot water at the sink and wash-basin, the top heater only is used, and provides 6 or 7 gallons of hot water. The temperature of the water will depend, of course, on the setting of the thermostat controlling the top heating element. This element has a loading of 500 watts, and the lower heater, fitted near the bottom, has a loading of 2,500 watts and is master-controlled by a 15-amp. foot-switch. This on/off switch, marked "Sink" in the off position and "Bath" in the on position, controls the current to the lower element and thermostat (Fig. 105). When switched to "Bath" the circuit to the lower heater is made, and the thermostat controls the current and the temperature of the water according to the setting of the thermostat. Thus the total contents (20 gallons) are now heated to the desired temperature. The settings of the two thermostats need not be identical. For example, the top thermostat may be set at 160 deg. Fahr. for normal use and the lower 140 deg. Fahr. for bath use.

Normally only the top heater is in circuit, and when large quantities of water are required for baths or washing clothes, the lower heater may be brought into use.

It will be seen, therefore, that appreciable savings in electric energy are made, since, during normal periods, heat losses take place only through the top portion of the heater, e.g., the surface area in respect of 6 or 7 gallons of water.

Generally, it is found that the 6 or 7 gallons of water are sufficient for normal requirements, and since the lower heater has a comparatively high loading of 2,500 watts, the remaining 13 gallons are heated in about an hour.

A number of the recognised electric water-heater manufacturers are making this type of water-heater. One manufacturer has adopted standard types of elements, each having a loading of 500 watts. These are interchangeable, there being one in the top heater plate and five in the bottom to give the 500 and 2,500 watts loading respectively. These fit into a horizontal fitting in the same way as a lamp, and are easily withdrawn, it not being necessary to draw off the water in the tank, since they are housed in watertight metal tubes. As a further means of control (to switch off the top heater when the water-heater is not required for long periods), a 3-kW. switch-plug may be installed or, if desired, a 15-amp. main switch.

Plumbing.—The plumbing arrangements are similar to those described for the pressure heater. A vent or expansion pipe is essential, and must be taken to the highest point and, where possible, should terminate in a bend over the cold-water tank.

When used in conjunction with an existing solid-fuel system, the plumbing arrangements are as shown in Fig. 104. Two vent or expansion pipes are required. No other system of piping will be satisfactory, nor is it possible to dispense with one of the vent pipes.

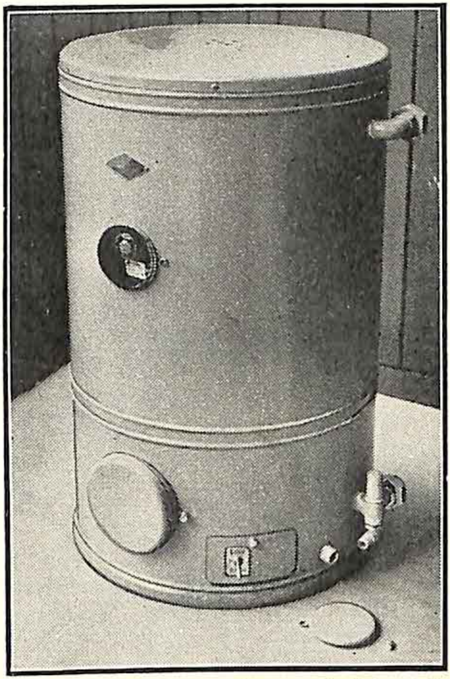


FIG. 102.—Dual water-heater (Sadia) of 20 gallons capacity, having two sets of elements. One near the top (cover removed), which provides 6·7 gallons of hot water, and one in the base which is controlled by foot switch. This is used when large quantities are required, viz., for a bath.

When the boiler is lighted, the top heater may be left on so that hot water is available should the boiler fire go out. If the solid-fuel boiler provides sufficient heat the electric element will not operate, since the thermostat will not switch it on until the temperature of the water drops below the setting of the thermostat.

Where head room is restricted, such as in a bungalow, and the distance between the cold-water storage tank and the water-heater is not sufficient to give adequate pressure, a non-return valve is incorporated in the expansion pipe about 1 ft. below the water from the taps.

A modified model of the dual water-heater is also made which is connected to the Circoil unit. This unit (Fig. 106) is installed in the flue system of a boiler or solid-fuel fired space-heater, harnesses the waste heat in the flue, and transmits it to the electric water-heater; thus acting as a booster. Appreciable economy is attained with this unit.

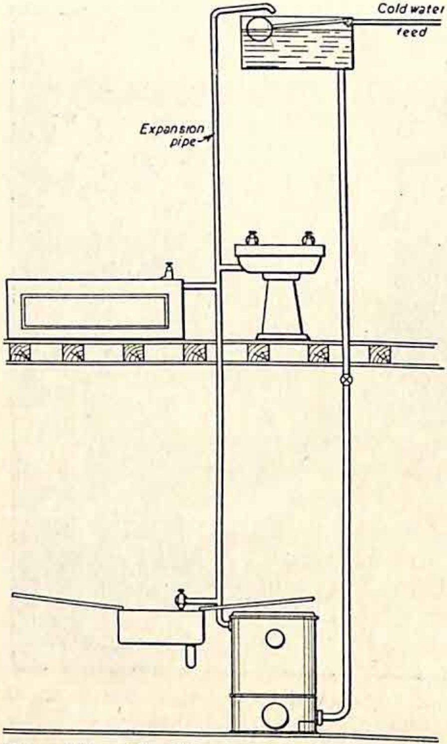


FIG. 103.—Plumbing connection of dual water-heater. A separate cold water storage tank controlled by ball valve is essential with this water-heater.

Thermostats.—These should not be tampered with other than for initial adjustment, but should they be removed, it is essential that the correct ones are replaced in their respective sockets. The bottom thermostat will control 15 amps., but the top one only 5 amps. As with all thermostats, if the supply is D.C., mercury switch types must be used.

Jet Water-heater.—Another water-heater on the market is a quick-acting dual-vessel model termed a jet water-heater (Fig. 107). Of unusual construction, it is essentially hand controlled, with a thermostat incorporated to prevent the water boiling and to minimise "standing" losses.

The water-heater is a pressure-type multi-point heater of 13 gallons capacity, and must be fed with cold water through a break pressure ball-valve cistern. For use in blocks of flats fed from a common cistern, a break pressure tank measuring 20 in. wide by 12 in. deep with 7-in. projector and containing the usual ball-valve equipment, can be obtained from the makers.

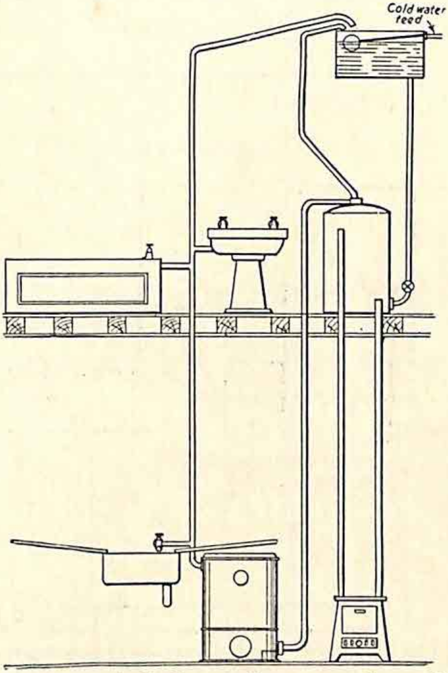


FIG. 104.—A dual water-heater can be used in conjunction with existing solid fuel water heating system. Plumbing connections are similar to those made with the normal pressure type water-heater used in conjunction with solid fuel system, as will be seen in the diagram.

The chief feature of its construction is that it consists of a small inner water container, which houses the element, and is situated within a larger outer container.

Its chief advantage is that 1 gallon of water 165 deg. Fahr. or 2 gallons at 120 deg. Fahr. (washing-up temperature) can be drawn off within four minutes of switching on. The thermostat, when set at 175 deg. Fahr., cuts off after a period of 6½ minutes. Larger quantities of hot water can, however, be obtained by turning a valve lever so that circulation takes place through the inner heat-insulated vessel which contains the heating element, into the surrounding outer container. This outer container is lagged, so that when the storage water is heated losses are reduced.

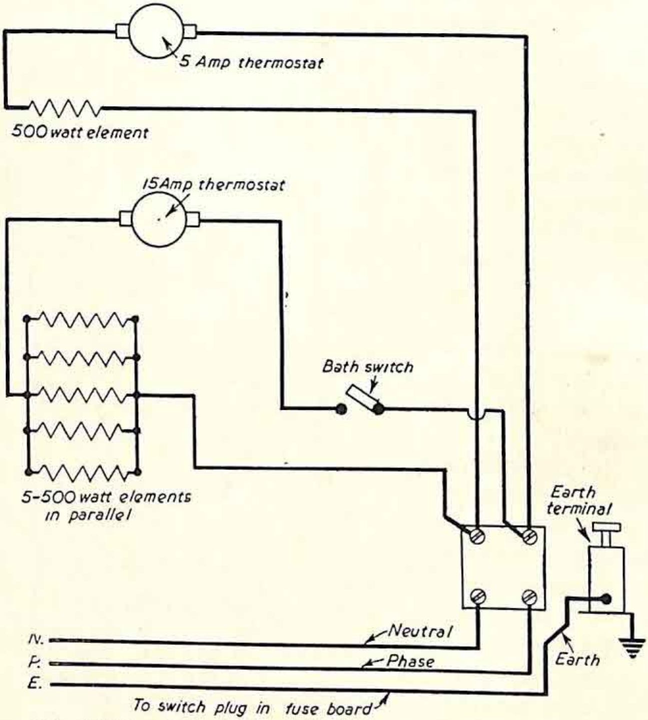


FIG. 105. Wiring diagram of Sadia 20 gallons dual water-heater. It will be noted that this consists of two independent circuits, each controlled by a thermostat. The larger heater, 2,500 watts, is also controlled by a switch and does not operate until this switch is "on". Connection to the electricity supply may be to a 3 kW. heating point, fuse-board, or a separate main switch.

The method of operation enables a useful quantity of water to be drawn off while the main contents in the outer chamber is heating. This rapid heating of small quantities of water is also useful after a bath has been taken.

As with all pressure types of water-heater, the ball-valve tank must be mounted above the highest outlet and a vent or expansion pipe provided from the heater outlet to the top of the cold feed-tank. The maximum head of water must not exceed 25 ft.

Both the outer and inner vessels are of Monel metal with electrically welded seams, while the outer casing is finished white enamel.

The water-heater may be stood on the floor under the draining-board, but is fitted with an easily removable flat table-top cover.

The element has a loading of 3·45 kW. and can be connected to a normal heating circuit. A special thermostat must, however, be fitted where the electricity supply is D.C.

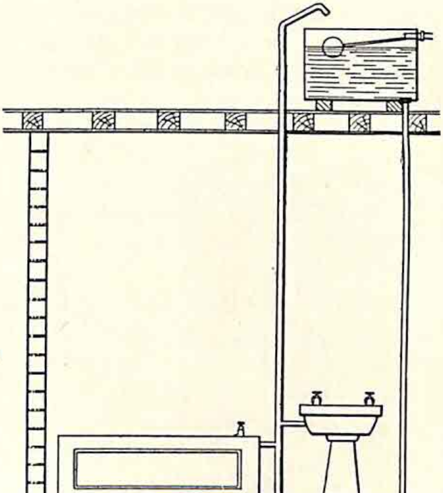


FIG. 106.—A modified pattern of the Sadia dual water-heater. Two extra plumbing connections are made and operated in conjunction with the Sadia Circoil, waste heat from a solid fuel heater being utilised. The Circoil is fitted on top of the solid fuel fire.

Installing the Jet-heater.—The pipework should be carried out as in Fig. 107*b*. When this is completed, the system should be given a water test and an examination carried out by removing the table-top to ascertain whether the water connections have been disturbed. The thermostat should then be set to 175 deg. Fahr., the electrical connections made and the current switched on.

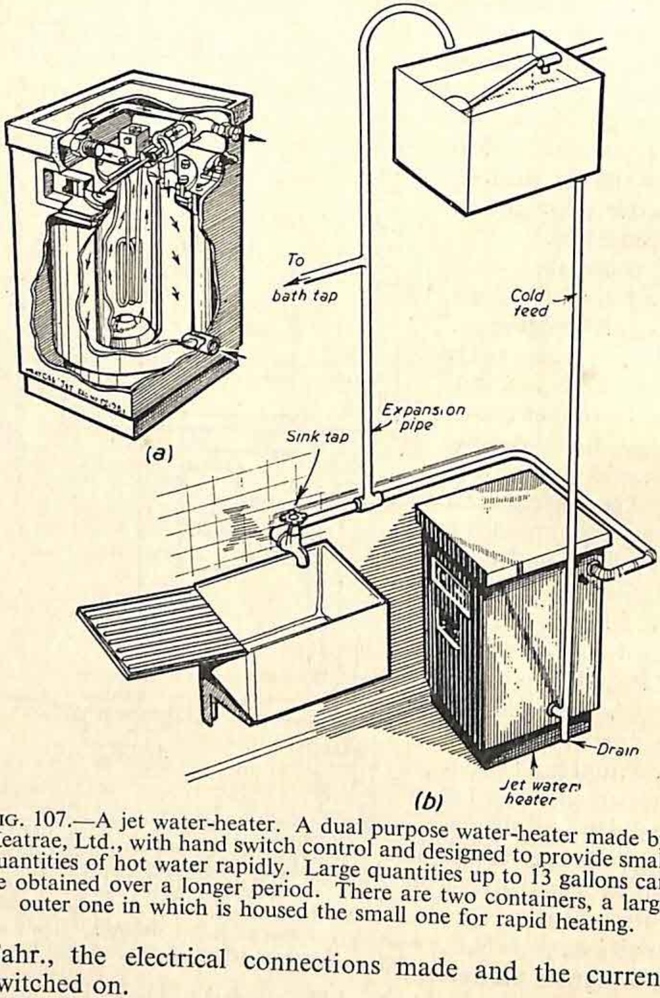


FIG. 107.—A jet water-heater. A dual purpose water-heater made by Heatrae, Ltd., with hand switch control and designed to provide small quantities of hot water rapidly. Large quantities up to 13 gallons can be obtained over a longer period. There are two containers, a large outer one in which is housed the small one for rapid heating.

Two or three tests should then be made. First, a small quantity of water with the water-valve off (lever pointing left), and then on full water content, by turning water-lever to the right.

Should the water-heater not operate correctly and all the electrical connections are sound, or should the heater fail after use, the makers should be consulted.

Instantaneous Water-heaters.—Commonly termed an electric geyser (Figs. 108 and 109), because it functions similarly to a gas geyser and heats the water immediately preceding its use. There is therefore no water storage. Electric geysers have not gained in popularity, as have their gas counterparts, largely owing to their having an element of high loading which not only requires a comparatively heavy wiring circuit, but is not accepted by many electricity authorities.

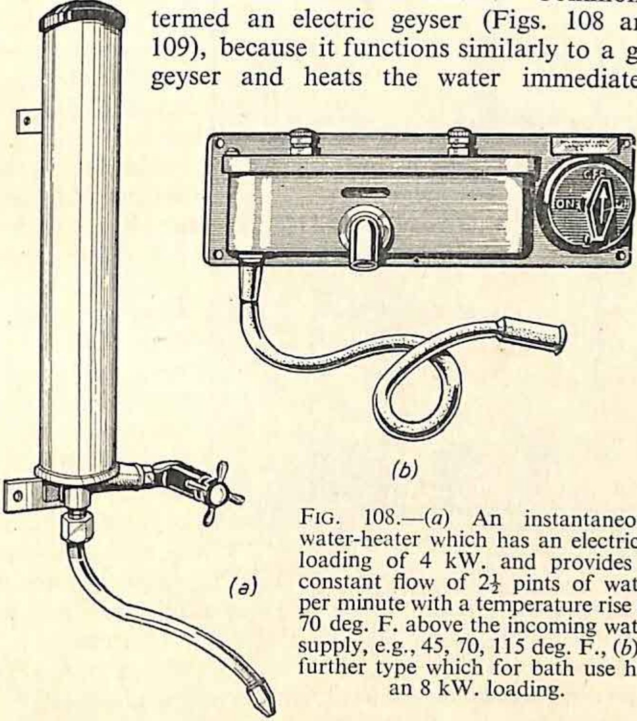


FIG. 108.—(*a*) An instantaneous water-heater which has an electrical loading of 4 kW. and provides a constant flow of 2½ pints of water per minute with a temperature rise of 70 deg. F. above the incoming water supply, e.g., 45, 70, 115 deg. F., (*b*) a further type which for bath use has an 8 kW. loading.

Supply authorities who allow them to be connected to their mains charge higher rates for the electrical energy consumed, thus making them less economical.

Advantages and Disadvantages of Geysers.—Since there is no water stored, geysers are of small dimensions, and therefore take up little space. Space occupied by an electric geyser is less than that of a gas geyser and, of course, no flue is required. A further advantage is that there are no standing losses as with a thermal storage-type water-heater. Chief advantage is, of course, the size or kW. rating of the element.

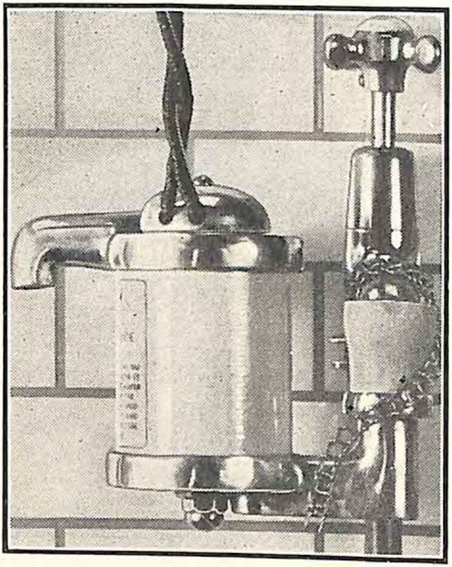


FIG. 109.—A small instantaneous water-heater which can be placed on the outlet of an ordinary cold water tap. The local supply authorities should be consulted before any of these are installed.

Compared with a normal domestic gas geyser which provides a hot water output (40 deg. Fahr. temperature rise) of 2 gallons per minute, an electrical loading of 14 kW. would be necessary. To obtain a hot water output of 3½ gallons per minute (40 deg. Fahr. rise in temperature), as obtained from a large domestic gas geyser, would require an electrical loading of 24½ kW.

Since the current rating on a 240-v. supply would be 56 amps. and 102 amps. respectively, it will be seen that the cable would be of prohibitive size unless the equipment were installed near the meter position.

A further disadvantage of the instantaneous electric water-heater is that, in view of the high heat transfer in a short space of time when the water passes over the elements, the immediate thermal efficiency is much lower than that of the thermal-storage type. Steam is produced, which means loss of heat, and considerable scaling occurs. This loss is, of course, counterbalanced to some extent by the absence of standing losses.

Instantaneous water-heaters are made in about two ranges of loading, one range for wash-basin and sink between 4 and 6 kW., and for the bath type 8–12 kW., the lower value being for a small bath, or where the user does not mind the greater inconvenience of waiting.

When choosing such a water-heater, however, it is advisable first to ascertain the requirements of the electricity supply authority.

In hard-water districts, such as London, geysers are not generally recommended, due to the heavy scaling which would occur on the element. Geysers, not being storage or pressure types, can feed only one point or two adjacent points, such as bath and wash-basin where a swivel outlet spout is incorporated.

In dental surgeries and where small quantities of hot water are required only occasionally, a small geyser is, of course, a very useful appliance.

Unlagged Water-heaters.—Where low initial cost is of primary importance, and continuous hot water is not essential, a factory produced unlagged self-contained water-heater will be satisfactory. This is an intermediate heater between a storage type and the geyser.

It usually comprises an unlagged water container which will supply one outlet only, such as a bath, and can be connected direct to the water main. In Fig. 110 the heater feeds two adjacent points, bath and wash-basin, and is therefore a pressure-type heater.

Resembling the single point storage heater described earlier, but unlagged, it often works on the displacement principle, having an open outlet into the receptacle; the hot-water control being on the cold-water inlet.

Most models of this type have removable lids for cleaning out the container, are finished in white enamel and are fitted with brackets for fixing to the bathroom wall over the bath. Immersion-type elements are fitted, and the loading is usually in the order of 4 kW. for the 12-gallon size, which is the most useful model. This is high compared with the

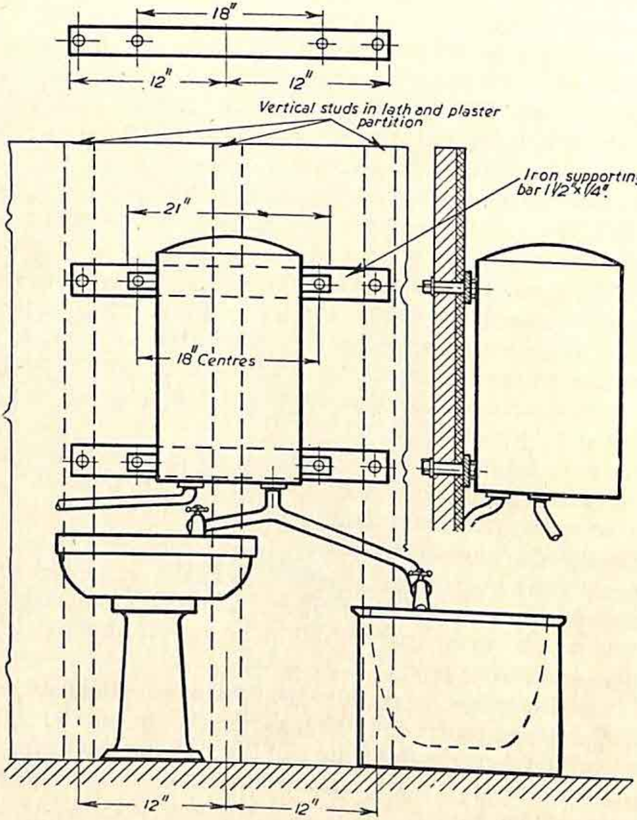

18"
12"
12"
Vertical studs in lath and plaster partition
Iron supporting bar 1½"×¼"
21"
18" Centres
12"
12"

FIG. 110.—Where there is no solid wall to fix a water-heater and a lath and plaster partition must be used, an iron batten should be fixed to the vertical studs and drilled so that the water-heater can be bolted on the batten.

thermal storage types; a 12-gallon size normally having a loading of 1·2–1·5 kW.

Heating up time is, however, reduced, which is between one and two hours, depending on the temperature desired.

Pipework and Plumbing.—Where a hot-water system is already installed, it is usually possible to utilise all or part of the existing pipework. Otherwise one must start from scratch and install the best possible system.

Installing a self-contained storage heater in an existing system is, however, more difficult and requires careful planning and inspection.

Where the system is old—e.g., 20 years or more—or it is apparent that the hot-water pipes have operated at high temperatures with the resulting furring of the pipework, do not hesitate to scrap the system. This safeguard is of particular importance in London and other hard-water districts, for inspection of pipes which have been in use for even less than ten years in London has revealed heavy furring, and a ¾-in. iron pipe has become almost completely choked.

XVI

PIPING AND ELECTRICAL INSTALLATION OF WATER-HEATERS

APART from cutting out a length of pipe for inspection, the only true examination can be made by removing the inspection cover of the hot-water storage tank. Heavy scale deposit will indicate that the water has reached high temperatures and even perhaps boiling point. The outlet of the flow-pipe from the boiler should also be closely examined.

Alternatively, a new system may be run which can be carried out by installing either a storage heater at each outlet point, leaving the existing hot-water taps in position for use when the old solid-fuel system is operated, or by installing a new system with a pressure type of heater to operate independently and in parallel with the solid-fuel system.

When it is decided to install independent electric storage water-heaters—e.g., one 1½ or 3 gallons—at the kitchen sink, a 12–20-gallons type to serve both bath and wash-basin and additional small heaters at other wash-basins, the only plumbing necessary when displacement type or single-point heaters are installed is a cold-water feed.

General and best practice is to feed the kitchen point from the cold-water mains so that the water-heater can be used for culinary purposes, and other positions from the low-pressure cold-water cold-storage systems. Since cold-water outlets at these points are normally fed from the low-pressure system, the only plumbing necessary in all cases should be a short piece of piping. This piece of piping should be the same as the main system—e.g., iron, lead or copper—but since iron piping is difficult to install without cutting tools, including a set of stocks and dies, the simplest method, where possible, is to insert a special brass to copper fitting at the point where the cold-water outlet is made.

Special compression fittings are made for this purpose. If unobtainable, other types of brass to copper conversion fittings should be used, one of the simplest being the "Yorkshire" type, further details of which are given later.

Plumbing a joint on lead pipe is not an easy matter for the amateur, and in cases of difficulty either a plumber should be called in or a brass-to-lead fitting obtained for insertion between the joint near the cold-water outlet and the heater.

These are easily fitted provided proper jointing compound is used. A piece of lead pipe can then be obtained with the conversion unions fitted. A piece of rubber pipe will operate satisfactorily, but should be used only as a temporary expedient.

When a complete water-heating system is installed to operate in parallel with an existing system, the only alteration to the existing installation will be an outlet from the existing cold-water ball-valve cistern. This job can be otherwise regarded as a new installation, of which more details are given later.

Types of Piping.—When carrying out a new installation the question of the best type of piping to use always arises. For the cold-water side of the installation it is immaterial, but for the hot-water side copper is undoubtedly the best. At present, however, the decision must depend on the materials obtainable.

If iron pipe is available, care must be taken with the joints; if it is to be installed in existing property considerable cutting away and making good of the house structure and decorations may be necessary.

Lead pipe, on the other hand, can be installed with minimum of cutting away, but care is necessary in handling, and a complete installation should be carried out by a plumber, or troubles may develop. Copper piping, on the other hand, besides being easier to obtain at present than lead piping, is simple to install.

Special capillary fittings of the "Yorkshire" type are made and, if used, the job can be carried out with little difficulty by an amateur.

Copper piping also has a higher operating efficiency and shows considerable saving in electricity when used for the hot-water system, as will be shown later. The "Yorkshire" fitting, which is used in conjunction with copper tubing, is made in all types, and eliminates bending of the piping. These fittings include elbows, bends, obtuse bends, tee fittings and a wide variety of special fittings and couplings, and are also incorporated in stop-cocks, valves and waste traps to eliminate plumbed joints.

A fitting is made to fit each size of piping, and the base of the fitting contains a channel of solder. The copper tubing is well cleaned and smeared with flux, and is pushed into the base of the fitting up to the shoulder. When in position, the heat from a blow-lamp is played on the fitting, and the solder from the channel is drawn by capillary attraction into the joint, and the whole is fused together, forming a copper–zinc compound. It is almost impossible to overheat a joint. Heat is applied until a ring of solder appears round the mouth of the fitting.

Since tube of various gauges is available—it is important to ensure that the gauge number on the fitting is identical with that of the tube.

When necessary to take a joint apart, for alteration to the system or for other reasons, both the tube and the fitting can be used again. First the fitting is re-heated and the tube withdrawn. To re-make the joint, the fitting and tube are re-heated until the solder ring is around the fitting mouth as before. If a new untinned tube is used, to re-make a joint this must be cleaned and evenly fluxed. When heated, solder is applied to the mouth of the fitting.

No trouble will arise with these joints if properly made. To ensure no faults or leaks will occur, the tube should be cut square with a hacksaw and burrs removed and the outside of the tube properly cleaned with fine sandpaper (not emery), or steel wool. Each joint takes a minute or so to "sweat", and when installing a copper tube system all lengths can be cut, each cleaned and fluxed, and inserted into fittings before any "sweating" is carried out. When all the pipework is ready, the blow-lamp can be prepared and each joint "made". Care must be exercised to ensure that the tube is pressed "home" into each fitting and that no joints are forgotten, or, when the water is turned on, leaks will occur.

If a leak does occur in a horizontal pipe, due to faulty workmanship, difficulty may be experienced in either re-making the joint or removing the fitting, owing to the presence of water, which will prevent the fitting heating up and melting the solder. Water must therefore be drained out first. If

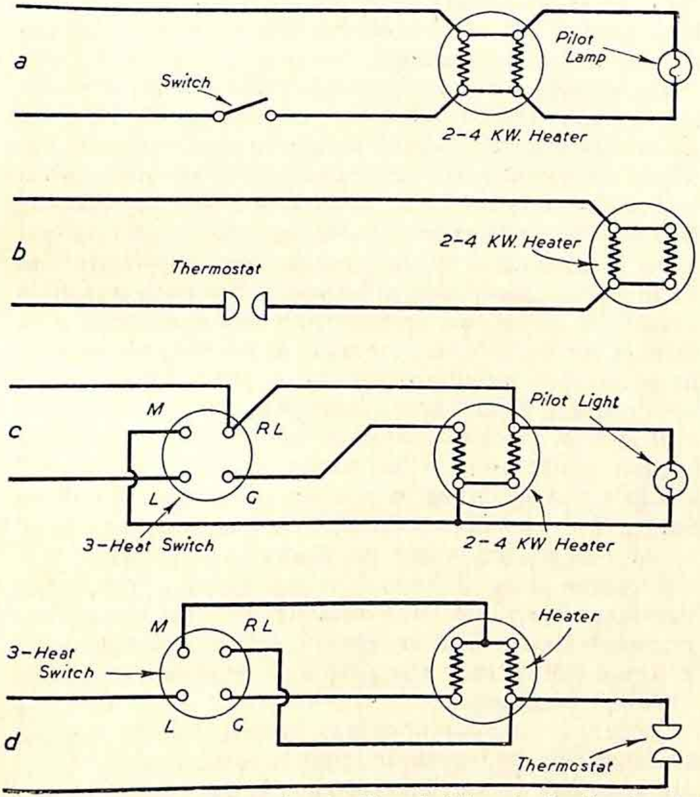


FIG. 111.—Four methods of controlling electric water-heating installations. (*a*) Is a normal hand-controlled circuit; (*b*) is a conventional thermostatic control with no switch; (*c*) is the converted three-heat switch control with pilot light, and (*d*) is a combined thermostatic and three-heat switch control circuit.

later extensions are contemplated, tee-fittings may be inserted in the place of couplings, and a stop end or cap inserted in the unused tee. This practice saves work later.

Fixing Water-heaters.—It is essential that water-heaters be properly fixed, or considerable damage will result from their falling out of position.

The weight of a water-heater full of water is not always appreciated. Since 1 gallon of water weighs 10 lb., a 12-gallon water-heater, which weighs approximately 72 lb. when empty, will weigh 190 lb., or over 1 cwt. more, when loaded. A good brick wall should be chosen, so that rag bolts can be used. These are well cemented in, and the best fixing is obtained if the hole cut for each bolt is made as small as possible. If the wall is lath and plaster, it is often possible to chose two upright studs and place bolts right through the wall. Where the studs do not coincide with the fixing brackets, stout wood slats or iron bars should be obtained and drilled accordingly (Fig. 110). One bolt of each should, if possible, coincide with the stud.

Many party walls in bathrooms are made of "breeze" blocks or cavity bricks, which are not suitable for direct fixing. Bolts should pass through the wall, with large metal washers on a wood or iron bar placed on either side.

Provision must be made for the overflow pipe when installing cistern-type water-heaters, and head room for inspecting the small cistern should also be provided.

Room below the heater must also be allowed for withdrawing the elements.

Since a vent or expansion pipe is necessary with a pressure-type water-heater, the heater must be fitted in a position to allow the uninterrupted rise of water in this pipe. Although these usually terminate in a bend over the cold-water cistern, they may terminate elsewhere, provided they are at least a foot above the highest level of the cold-water system. It is good practice also to allow an extra foot for each 20 ft. rise, since 13 ft. of cold water will support 14 ft. of hot water, the former being, of course, of higher density. If the expansion pipe is not high enough, a few pints of water will be ejected each time hot water is drawn off. Two or three draws-off in quick succession will result in wastage of hot water and a higher operating cost.

It is always desirable to install a cold-water cistern at the highest point to produce the most pressure on the system. Where there are restrictions in space and a displacement single-point heater is installed, erratic operation may result. When the cold-water inlet is operated the hot water flows, but after about one minute the flow ceases and then gushes out and stops again. This is due to insufficient pressure, the hot-water outlet being greater than the cold inlet. It can be cured by either increasing the size of the inlet or by reducing the size of the outlet, the former being the better alternative.

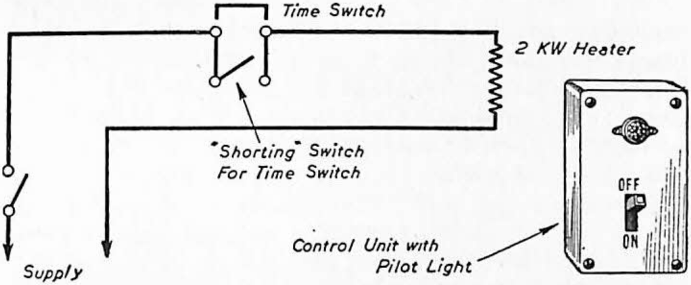


FIG. 112.—Time switch control with "bridging" switch.

Electrical Installation.—The water-heating electrical installation is normally a small proportion of the total work, and rarely consists of more than a simple electrical heating point, though with some forms of hand control more complicated circuits are employed.

The same principles apply to both the self-contained thermal storage heater and the conversion installation.

Where thermostatic control is adopted—and it is with all factory produced thermal storage heaters—wiring need consist of only a single circuit terminating in a switch-plug adjacent to the heater. This circuit may be taken off a spare point of a heating distributing or fuse-board, but where none is available it may be necessary to install a separate circuit right back to the meter position. Here a separate main switch and fuse unit will be necessary. Such an independent circuit is particularly desirable where special low rates of charge are available from the electricity supply authority for water-heating.

An alternative to a switch-plug, at the heater end of the circuit, can consist of a special water-heating control panel which incorporates a red light to indicate when the current is on. This is not necessary with thermostatically controlled installations, since the heater is usually left in circuit continuously; the thermostat automatically controlling the current to the heating element.

Lead-covered cable, vulcanised rubber insulated (V.I.R.) in conduit and tough rubber sheathed (T.R.S.) are all suitable wiring systems for the circuit. Normally the type of cable employed in the main installation—e.g., house lighting, heating, etc.—should be used for extensions, but it is sometimes desirable to adopt an alternative method. For instance, should a watertight installation be desirable for outdoor work, or lead-covered cable to obviate interference with decorative schemes, a departure from normal practice is justified.

Provision for earthing the electrical apparatus is necessary, and where steel conduit, lead-covered cable or T.R.S. cable with earth is employed, no further earthing conductor will be necessary. Otherwise, a separate earthing wire is required, which must consist of a bare tinned copper cable of a size of not less than 7·029. This is a standard cable stocked by most electricians.

Switch-plug.—A 5-amp. switch-plug and 3·029 cable is suitable for water-heaters having loading up to and including 2·0 kW. Above this a 3 kW. (15 amp.) plug must be used with circuit wiring of a size not less than 7·029. A suitable lead from the plug to the heater comprises 3-core flexible cable covered with tough rubber sheathing. Where large heaters are installed, having loadings of 4 kW. and above, special circuits must be installed with suitable control gear, the capacity of which will depend on the electrical load. Although switch-plugs should, where possible, be installed adjacent to the heater, special precautions must be taken in bathrooms and similar locations to ensure that the plug cannot be reached by a person in the bath, or when operating a water-tap at the sink.

In fact the installations should meet the conditions and recommendations laid down in the I.E.E. Regulations for the Electrical Equipment of Buildings, and conform to the Electricity Supply Regulations.

Hand Control.—This is used on non-thermostatically controlled installations, whether of the conversion type or factory-made non-lagged heaters. Switch control is essential, and may consist either of a switch-plug or control unit. Where a switch-plug is used, a pilot light should be fitted so that the user can see when the heater is on. Special control units for water heating are available, and usually include pilot lamps. Omission to install a pilot light on hand-controlled installations may result in the heater being left switched on. The water will then get too hot and probably boil, and the tank may burst, with consequent damage to ceilings and so forth.

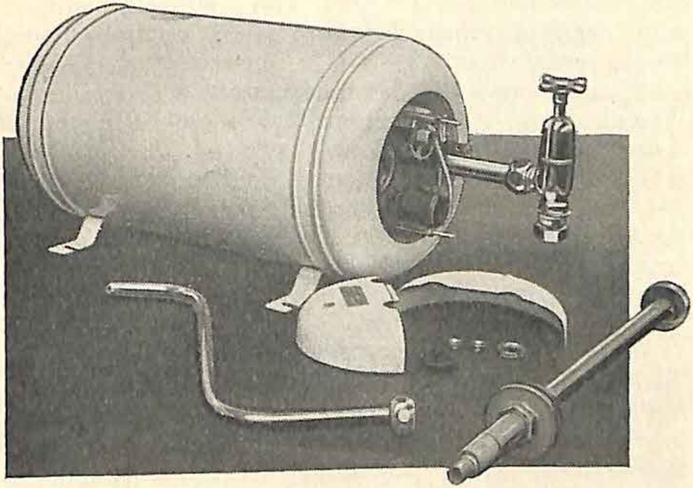


FIG. 113.—Hot water outlet removed from small displacement type water-heater. Note mushroom head of anti-drip device where scale usually forms. This must not be bent or otherwise damaged when scraping off scale.

A satisfactory method of controlling an installation of 2 kW. and above is by the three-heat method (Fig. 111). This switch gives a choice of high, medium and low heats. For general use low or medium is sufficient, but when a large quantity of water is required quickly, such as for a bath, the switch may be turned to high.

From the illustration it will be seen that to operate an installation by means of a three-heat switch, the heater circuit must be split into two parts. This is normally provided at the element terminals, for where a 1-kW. element usually, though not always, consists of a single element, a heater having a loading of 2 kW. or more consists of two elements. Where the heater consists of one element only, it cannot, of course, be adapted for three-heat switching.

On high the two elements are connected in parallel and give maximum heat; on medium only one element is operated and gives half heat, and on low the two elements are in series, which gives one quarter heat. Therefore, on low the heating effect of a 2-kW. heater would be only ½ kW.

No switching arrangement will, however, replace the thermostatic automatic control, which should be used where possible. A good alternative is made possible by using a time-switch. This is installed in the circuit (Fig. 112), and may be set to "cut in" about an hour before hot water is required. Where this is used, it will be found advantageous to set the switch for early morning supplies of hot water, and, by incorporating a hand-switch, the time-switch may be bridged during the day to give normal hand operation.

Heat Losses in Pipework.—Heat losses should be reduced to a minimum to give the most efficient installation. These occur in a number of ways.

Loss of heat occurs in the storage vessel. From an unlagged conventional hot-water storage tank the losses are considerable, and if the installation is thermostatically controlled and in continuous use, the system would be uneconomical. Adequate lagging of the tank reduces such losses to reasonable proportions. Losses in factory-produced thermal storage water-heaters are comparatively low.

Figures for the various sizes were given earlier in this series.

Remaining losses are pipe losses. These are due to (*a*) heat absorbed by the metal on the pipe, e.g., copper or iron; (*b*) radiation and convection loss in the pipe if kept hot—this varies depending on the pipe and its location—and (*c*) heat stored in water where this is allowed to cool. Water in a pipe which serves a tap that is seldom used will become cold after use, and results in a "dead leg" of water.

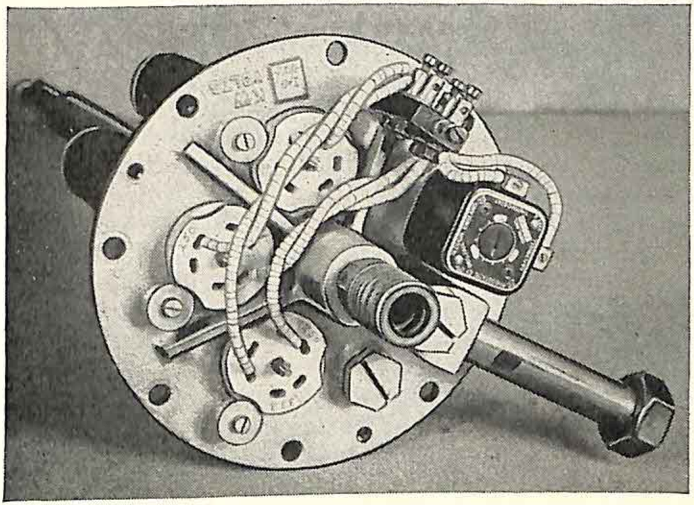


FIG. 114.—Apparatus-plate assembly of 1 kW. displacement type water-heater removed for inspection.

Since the metal in an iron pipe is greater than that in one of copper, the losses from the heat stored in the metal are greater in the iron than in the copper. For example, if the temperature of the water is 180 deg. Fahr., the losses per foot run in an iron pipe of ½-in. bore are 4·4 watt-hours, compared with 1·1 watt-hours for copper. Therefore, each time water is drawn through a pipe having a "dead leg" of cold water, four times the losses will occur in iron compared with copper.

Radiation losses are of importance only where the water is being continually drawn off. These amount to approximately 20 watts per foot run of iron pipe. Losses from copper pipe (unpainted) are about 60 per cent. of this, depending on the length of pipe.

Convection losses are due to the free passage of air around a pipe, and are greater when the pipes are exposed to the cold air. Since the surface area of an iron pipe is greater than that of copper, convection losses in respect of the iron pipe will therefore be greater. If the water in a pipe is allowed to become cold, radiation and convection losses are of no account, since all the heat is lost anyway.

Loss in heat stored in the water content where the water has cooled is about 3 watt-hours for ½-in. pipe and 7·5 watt-hours for a ¾-in. pipe. These losses can be reduced only by using a pipe of lowest possible bore and ensuring that pipe runs are short.

Lagging Pipes.—Losses of heat in pipes are reduced to about one-fifth when an iron pipe is lagged. The losses from a lagged copper pipe are, of course, the same as that from a lagged iron pipe.

While lagging of pipes appears to result in appreciable savings of current, in practice this is not so.

There is nothing to be saved in lagging a pipe which is infrequently used—e.g., pipe feeding the bath outlet. Generally, if the intervals between draw-off are greater than twenty minutes no saving accrues from lagging, since the water has cooled in spite of it. If long runs of iron pipe are made to frequently used taps, such as the kitchen tap, lagging should be carried out. Consideration should also be given to lagging a copper pipe where the run is excessive and the pipe is exposed, but in such cases savings are best made by installing an independent water-heater at this point.

A greater amount of energy can always be saved by reducing the amount of heat absorbed by the water and pipe. This is eliminated entirely when a separate heater is used, but the losses of the heater must be considered. Copper pipes are superior in this respect to iron. Owing to the smoother bore of copper pipe, and the use of easy bends, it is often possible to reduce the pipe bore when using copper. For instance, $\frac{1}{2}$-in. copper pipe can be used for the same purpose as $\frac{3}{4}$-in. iron pipe.

In normal circumstances about 20 pints of cold water have to be drawn off a 15-ft. "dead leg" of $\frac{3}{4}$-in. iron pipe before the water temperature reaches 150 deg. This compares with 8 pints from $\frac{3}{4}$-in. copper and 6 pints from $\frac{1}{2}$-in. copper pipe.

Maintenance.—Little maintenance is necessary for electric hot-water systems over a period of years.

The chief troubles arise from scaling. Small heaters of the $1\frac{1}{2}$-gallon and 3-gallon class may require de-scaling in hard water districts every six months where the thermostat is set high, and large water-heaters may require treatment every two years. In soft-water districts and where the thermostat is set low—e.g., 140 deg. Fahr.—de-scaling need be carried out only once every five years.

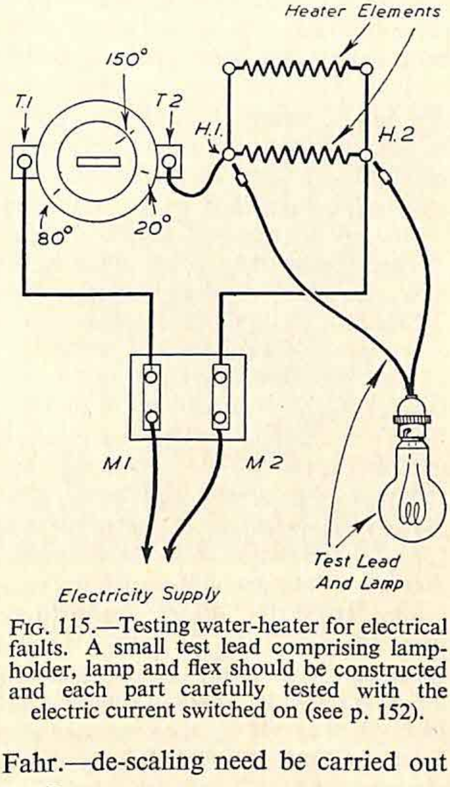


FIG. 115.—Testing water-heater for electrical faults. A small test lead comprising lamp-holder, lamp and flex should be constructed and each part carefully tested with the electric current switched on (see p. 152).

De-scaling is simple to carry out. First the electricity is cut off and the water drawn from the heater.

The thermostat and element (Fig. 114) may then be removed. The apparatus plate is then lifted off by removing the bolts or screws. A new gasket will be required before replacing the apparatus plate.

Most of the scale will be found on the casings of the thermostat and elements, and these should be well scraped. All scale should then be taken out of the container and the hot-water outlet inspected, since the scale usually forms here and restricts the flow of hot water through the outlet. Care must be exercised when de-scaling to ensure that the mushroom head (the anti-drip device, Fig. 113) is not damaged or bent, or this will not operate correctly.

Having cleaned the container, element and thermostat casings and obtained a new gasket, the apparatus plate may be refixed, taking care the gasket fits well and all bolts are well screwed home. The element and thermostat are now replaced, connections made, drain-plug fitted and the water turned on.

Thermostats may need adjusting, since the setting may have altered during the removal of the element.

In cases of doubt as to dismantling a water-heater the makers should be consulted.

Electrical Faults.—If the heater does not operate (water does not get hot) when the current is switched on, and the fuses are intact, and the current is at the switch-plug, it is most likely an element fault.

This can be ascertained by testing the terminals with a pilot light, which consists of a lamp-holder, short piece of flexible wire and a lamp (Fig. 115). If there is no light, the thermostat has probably stuck in the open position.

The terminals *T*1 and *T*2 should be bridged by a short piece of wire (Figs. 115 and 116) and the pilot-lamp test repeated. If no light, the fault lies in the wiring, but if the lamp lights, indicating an element fault, the element should be inspected. Where there are two elements, as in Fig. 115, rarely will both elements fail simultaneously. Therefore the connections at *H*1 and *H*2 should be carefully inspected.

Before removing the element, the connection should first be inspected, after switching off the current, and if this appears to be correct the element should be withdrawn.

The withdrawable-element type can be removed by releasing two nuts holding the porcelain former, after the electrical connections to the thermostats are removed. The tubular sheath and flat-blade sheath type cannot be removed, however, without first drawing off the water. These elements are then released by removing the large locknut. Practically all thermal storage heaters have withdrawable elements, and difficulty in removing the elements will therefore arise only in conversion installations where the element is immersed in an existing tank.

Rarely is it possible to repair elements, and they should be returned to the makers for replacement, quoting the voltage of the electricity supply. Damaged thermostats, too, cannot be repaired, and should be returned for replacement.

Water Boiling due to Electrical Faults.—Boiling of water can usually be traced to damaged or stuck thermostat; that is, stuck in the closed position.

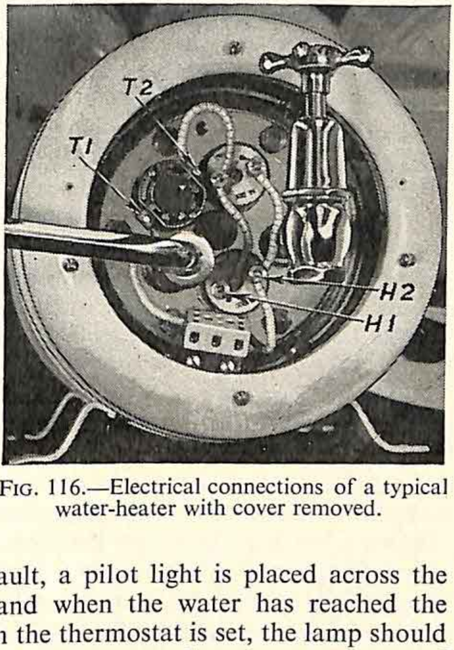


FIG. 116.—Electrical connections of a typical water-heater with cover removed.

To test for this fault, a pilot light is placed across the element terminals, and when the water has reached the temperature at which the thermostat is set, the lamp should be watched. If this does not go out when the temperature of the water is raised a few degrees above the setting temperature, a damaged thermostat can be suspected. No attempt should be made to repair it, but it should be returned to the makers.

More serious faults, such as continuous fuse-blowing, which is usually due to a short circuit or an "earth", should be corrected only by a qualified electrician. In fact, since the tests described must be carried out with the electricity on, they should not be attempted unless the user is a competent electrician.

Costs.—True costs of electric water heating are difficult, if not impossible, to estimate.

Consumption of electricity always depends on what use has been made of the water-heating system, frequency of baths, number in family, whether electric water heating only is used, or whether it is operated in conjunction with a solid-fuel system. Consumption will also depend on whether thermostatic control or hand operation is used, and the efficiency of lagging.

Where the water heating is solely by electricity, annual consumption in a small house of from three to five in family is in the order of 2,500–3,000 kWh. This cost depends on the charges for electricity, which for domestic electric water heating vary between ¾*d.* and 1¼*d.* per kWh., depending on the supply authorities.

Thus, where the consumption is as above and the charges are ¾*d.* per kWh., the annual amount will vary between £6 10*s.* and £7 10*s.*, or from 3*s.* to 4*s.* per week. At 1¼*d.* per kWh. and the same consumption the amount will be from 4*s.* to 5*s.* per week.

These figures have been taken for a thermostatically controlled installation, where the supply authority normally offers a low rate of charge.

When the installation is hand controlled, the charges per unit are often high, but, since the consumption of electricity is usually lower with hand control, the annual consumption of electricity is usually lower. These figures are given as a guide, and a guide only, since in practice they vary between households.

While electricity for water-heating approaches the ideal, due to its general efficiency and cleanliness, no existing system should be converted where it is obvious that it would not operate efficiently if so converted.

XVII

RUNNING ELECTRIC MODELS FROM THE MAINS

THERE are many occasions when it is more convenient, as well as more economical, to obtain the electrical energy for operating model trains and motors of all kinds from the mains than from batteries and accumulators. For some reason, however, there is a general tendency to avoid using the mains supply, because it is thought that there is a danger of receiving a shock. Such a possibility cannot be entirely ignored, but it certainly need not exist if reasonable and sensible precautions are taken and if correct methods of breaking down the voltage are followed.

The majority of models are designed to operate from a D.C. supply of between 4 and 12 volts, the current consumption varying between less than ½ amp. and about 3 amps. These voltages are by no means difficult to obtain when A.C. mains are available, but the position is not quite so satisfactory in the case of D.C. mains, where, strictly speaking, the voltage of the supply cannot be reduced.

Using D.C. Mains.—It is possible, nevertheless, to obtain the same effect by limiting the current to that required for the device to be operated; this is done by including a resistance in circuit as shown in Fig. 117. In this arrangement the resistance takes the form of a 100-watt lamp, which, assuming the mains voltage to lie between 200 and 240, will pass a current of just about ½ amp. Thus, if a motor rated at, say, 6 volts ½ amp. were connected to the two terminals indicated, the voltage obtaining between the terminals would be 6, or very nearly so. In the same manner, a 4- or 12-volt motor could be connected and the approximately correct voltage would be obtained.

This method is, however, not recommended, for two reasons: the first is that it is uneconomical, since the greater part of the mains supply is wasted; the second is that there is a risk of receiving a shock unless great precautions are taken to ensure that all parts connected to the mains (including the terminals of the motor) are very thoroughly insulated.

If this method is to be employed, the user should take precautions to ensure that children will not be able to touch the model when in use.

An Intermediate Accumulator.—It is far more satisfactory, when using D.C., to employ it for keeping an accumulator charged, the accumulator being used alone for actually driving the apparatus. The charging circuit is the same as that shown in Fig. 117, and care should be taken to ensure that the connections to the battery are of correct polarity. This can be determined by dipping the ends of two leads from the output terminals into a solution of salt in water. The negative lead will liberate a comparatively large quantity of gas in the form of bubbles, while the positive lead will give off fewer bubbles. In making the test the leads should be connected in series with a lamp, as in Fig. 117.

Low-voltage D.C. from A.C.—When the power supply is A.C., it is a very simple matter to step down the voltage without waste and without the least risk of obtaining a shock when using the model, no matter how carelessly the output leads are handled. The apparatus required is rather more complicated and expensive, but the cost is easily justified if the electrical device is used for fairly long periods. What is actually required is a mains transformer for stepping down the voltage, and a rectifier for turning the A.C. output from the rectifier into D.C. The complete apparatus is identical with an A.C. trickle charger, such as is used for battery charging at a slow rate, and a charger of this type provides a very convenient means of obtaining the necessary supply. There are several suitable chargers on the market. The most suitable of these units naturally depends on the output required, and thus on the particular model or piece of apparatus to be operated. All three are similar, in that they are provided with a length of flex and mains plug, tappings for different mains voltages, a plug for varying the voltage output, and a pair of output terminals.

A Home-made Unit.—When it is preferred to assemble one's own transformer-rectifier unit, this can be done by using a Westinghouse metal-oxide rectifier in conjunction with a mains transformer of appropriate type. Both these items can be bought ready-made. First it is necessary to decide on the rectifier, and the main details of the most frequently used types are available from The British Westinghouse Company; whilst the method of connection is shown in Fig. 118. It will be seen that the A.C. input voltage to the rectifier is greater than the D.C. output and also that a "ballast" resistance is included in the circuit. The purpose of this is to maintain the voltage uniform, irrespective of the actual current load.

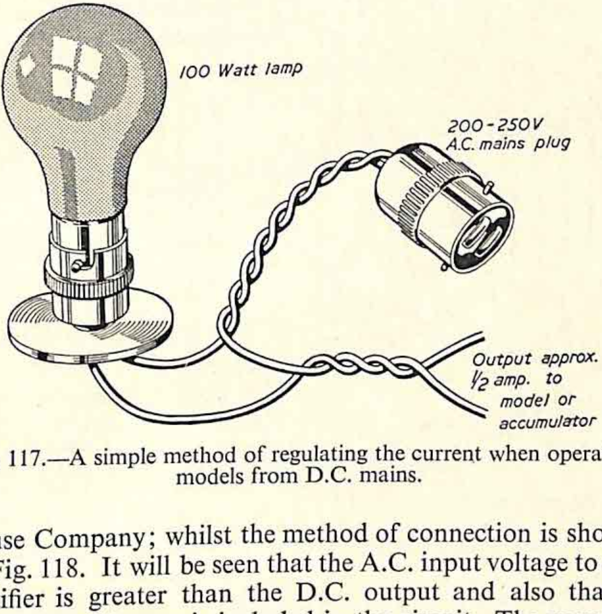

100 Watt lamp
200-250V A.C. mains plug
Output approx. ½ amp. to model or accumulator

FIG. 117.—A simple method of regulating the current when operating models from D.C. mains.

Transformer Details.—A transformer for any of the 6-volt output rectifiers can be made by using as a core six dozen pairs of Stalloy stampings. The primary winding should consist of 1,900 turns of 36-gauge enamelled wire tapped after 1,600, 1,720 and 1,840 turns (for 200-, 215-, 230- and

250-volt mains supplies), and the secondary should be wound with 20-gauge d.c.c. wire, allowing eight turns per volt, which is decided by the required input voltage.

In some cases, particularly for large-gauge model railways, a supply of 12 volts, 3 amps. D.C. may be required, and this can best be obtained by connecting two metal rectifiers in series, as shown in Fig. 119, to a transformer giving two outputs of 9 volts each (two secondary windings, 72 turns of 20-gauge d.c.c. wire each). Other "doubled" outputs can be obtained in the same manner, but it might be mentioned that rectifiers of the L.T. types should not be connected in parallel.

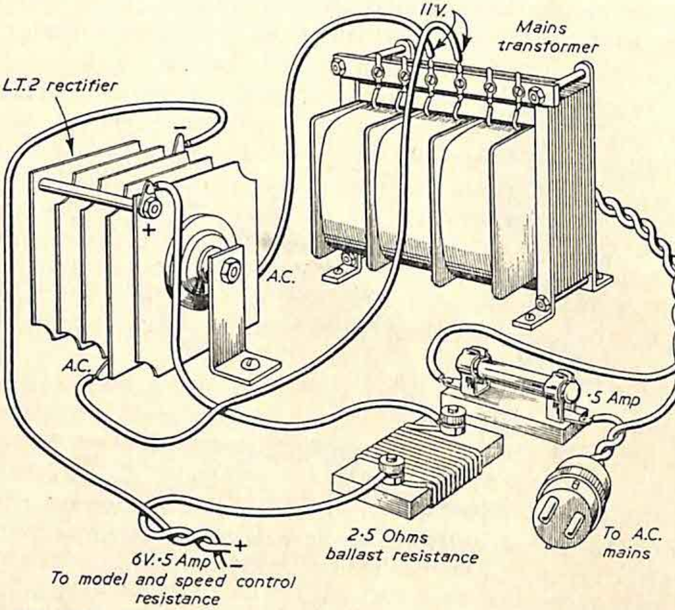


FIG. 118.—A transformer-rectifier unit for running models from the mains.

Obtaining 20 Volts A.C.—Many model railway engines are designed to operate from 20 volts A.C., and this supply can be obtained directly from a transformer without the need for a rectifier. A suitable transformer can be obtained ready-made or it can be made by using a primary as mentioned above, and using as secondary 160 turns of 24-gauge d.c.c. wire. The current output from this winding may be up to about 1·5 amp.

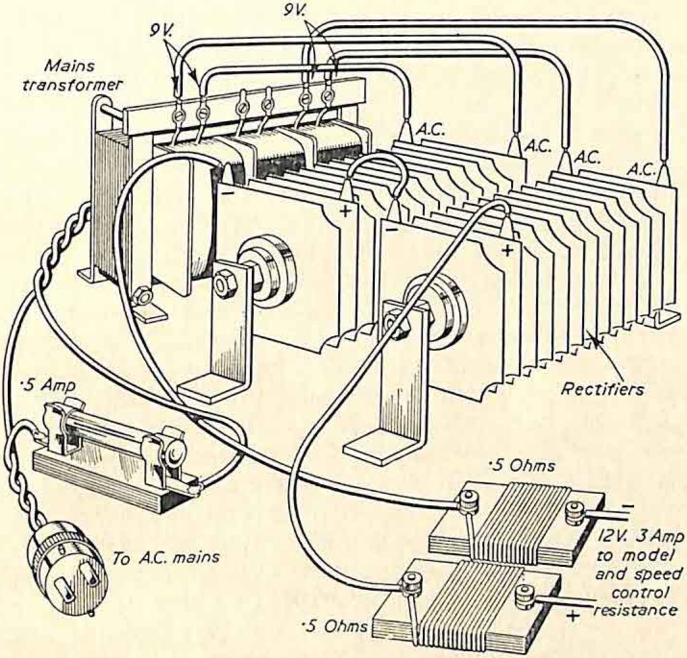


FIG. 119.—With these connections the normal D.C. voltage output is doubled by using two rectifiers in series.

When using any of the circuits referred to, it is a wise precaution to include a safety fuse in the mains lead to one of the primary terminals of the transformer. This is shown in the figures, and the rating should be ½ amp. With regard to the "ballast" resistance, this can easily be made by using 22-gauge Eureka resistance wire, the resistance of which is 1·1 ohm per yard. The correct length can be determined by dividing the figure just given into the resistance value appropriate to the rectifier in use. The wire may be wound on a strip of fibre fitted with terminals as shown in Fig. 119, the turns being slightly spaced, and the wire being wound on tightly to prevent the turns from slipping.

XVIII

MOTOR-DRIVEN APPARATUS

THE manufacture and production of fractional-horse-power electric motors is now an industry in itself. Whilst the majority of these small motors are for workshop purposes, their employment for ordinary household work is rapidly increasing. This does not mean the use of cumbersome machinery about the house, but portable electric motors, suitably encased, used as real labour-saving devices.

Manufacturers of these fractional-horse-power electric motors, faced with the problem of designing a motor to suit the requirements of alternating-current and direct-current users, have introduced a standard type of motor, known as the universal electric motor, to operate efficiently with either source of power. This aims at standardisation, and restricts the number of types of motors for the same purpose, so that there is no necessity for one motor for A.C. and another motor for D.C. On the other hand, the consumer, in the event of moving to another part of the town or country where the supply is different, need have no fear of his electrical apparatus being useless.

It is this type of motor—the universal motor—designed to operate on the standard electric supplies of 200–250 D.C. and 200–250 volts A.C., 50 cycles, which, in the majority of cases, is used for all domestic motor appliances.

It is a type known as the series-commutator motor, and, besides its use on either alternating- or direct-current supplies, its chief characteristic is its wide range of speed variation depending on its load, and its suitable starting torque for the applications mentioned below.

The Vacuum Cleaner.—Perhaps the chief application of the fractional-horse-power electric motor in the home is the electric vacuum cleaner. Cleaning by this method is effected by the suction of air either through the material to be cleaned or over its surface, and the collection of dust and dirt in a container (usually a canvas bag) fitted in or to the apparatus (see Fig. 120).

The suction is produced by a fan, driven by the motor and revolving at high speed. When necessary, the fan can be used for blowing instead of for suction.

In one of the most popular types of vacuum cleaner the motor and fan are housed in a polished aluminium case, one end of which forms a nozzle to work along the floor (as shown in Fig. 120), the whole apparatus being fitted with an undercarriage of wheels or runners for easy movement along the carpet or other article to be cleaned. Attached to the case is a trunnion-mounted pole, with shockproof handle containing the trigger or rotary switch to control the motor, the connection to the supply mains being made through the usual flexible cord (a few yards long) to the plug point.

When the nozzle of the aluminium casing is not required, provision is made for the attachment of a flexible hose, through which the air is drawn, and to the ends of this hose can be attached adjustable accessories for various cleaning and brushing purposes. In this particular type of cleaner ball bearings are fitted throughout.

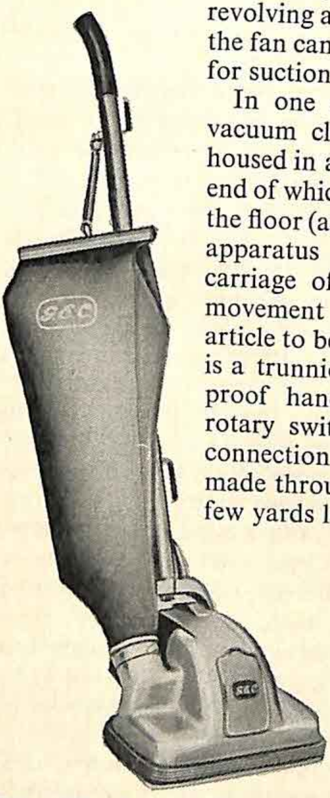


FIG. 120.—An upright vacuum cleaner which is driven by a motor.

A Floor Polisher.—The electric floor polisher, which is similar in constructional features to the cleaner, is used mostly for floors, linoleum and staircases. It consists of a motor mounted vertically and geared to one or more brushes of horse-hair or other suitable material. When two brushes are employed they revolve in opposite directions, as illustrated in Fig. 121. In this type of polisher two sets of brushes, mounted on a circular plate, are supplied, one set for spreading the wax and the other for polishing.

The switch mechanism is usually controlled by a movement of the pole or handle, and operates automatically on the motor casing, which embodies a switch.

The Electric Fan.—There are two types of electric fan for domestic use—namely, the exhaust or ventilating fan and the table fan (see Fig. 122). The former is used mainly for large kitchens, whilst the table fan is the popular type for use in the average home. This type of fan, if placed close to a suitable air inlet—say an open window—changes the air of a room. Some of these fans have an oscillating movement, the fan turning from side to side through an angle of about 100 deg., whilst some fans move up and down. These additional movements cause an air disturbance over a wide area and create less draught than the fan mounted on a fixed axis. In construction, the fixed model consists of a universal motor in a light cast-iron casing, with metal or moulded blades about 10 in. from tip to tip, suitably guarded, attached to the end of the motor-shaft. The motor is mounted to a stand fitted with a tilting movement, so arranged that it can be operated as a table fan or a bracket fan. Fitted in the base of the stand is a regulator which provides an "off" position and two speeds. Where higher-powered fans and oscillating movements are employed, it is usual to fit either an A.C. or a D.C. motor.

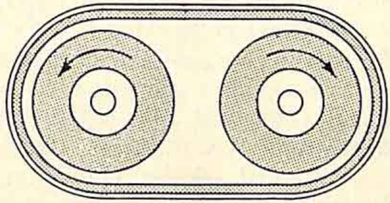


FIG. 121.—An underneath view of the floor polisher, showing the rotation of the brushes.

A Hair-drier.—The electric hair-drier consists of a universal motor mounted in a bakelite moulded case fitted with a shockproof handle, such a handle being necessary because the hair-drier may often be used whilst held in a warm, moist hand (see Fig. 123 on p. 167).

The casing contains, besides the motor, an electric heating element. The motor rotates a small fan which draws in air and expels it through a tube or nozzle (part of the casing) in which the heater element is located, thus producing a blast of warm air. The switch is fitted in the handle, and controls both motor and heater separately, so that hot or cold air may be obtained as required.

It should be noted that in the case of a hair-drier consuming, say, 650 watts, 600 watts is taken by the heating element, only about 40 or 50 watts being taken by the motor.

The Gramophone Motor.—The universal motor supplied for rotating the turntable of the gramophone is fitted underneath a top plate and below the turntable. As the motor is out of reach and sight of the operator, it is usually of the unprotected type (see Fig. 124).

The speed of the gramophone motor is controlled. In older models a system of sprung weights fitted to the motor shaft; the speed is governed and maintained at about 2,000 revolutions per minute. The motor shaft engages through silent reduction gearing with a vertical shaft carrying the turntable, the resultant speed of this shaft being about 100 revolutions per minute. This speed is adjusted to the required 78, 45, or 33⅓ r.p.m. by a brake-pad engagement controlled by a lever. Most gramophone motors nowadays are of the synchronous type and drive the turntable from the rim.

In the type illustrated, an automatic start and stop mechanism is fitted underneath the turntable and controlled by the movement of the pick-up arm. When the pick-up arm is resting away from the record (its normal non-playing position), the switch for the motor is "open", and the action of bringing the arm to the edge of the record for playing automatically closes the switch and starts the motor. When the arm has reached the playing end of the record, the mechanism automatically opens the switch and the motor stops again.

Current Consumption.—The consumption of electricity by the application of fractional-horse-power motors outlined above is so low that they can all be safely attached to the lighting circuit if the consumer has not a power point. In the accompanying table useful data concerning these motors is tabulated. See also table on page 168.

The number of hours use for a penny is based on the general power charge of about 1*d.* per unit.

Type.	Approx. H.P.	Watts Consumed.	Hours of Use for a Penny.
Vacuum cleaner .	$\frac{1}{8}$	200	5
Floor polisher . .	$\frac{1}{8}$	200	5
Fixed fan . .	$\frac{1}{50}$	40	25
Hair-drier . .	$\frac{1}{100}$	650	1½
Gramophone motor .	$\frac{1}{50}$	10	100

Having previously dealt with fractional-horse-power motors as applied to a small type of house, we now come to the applications of such motors in a larger household. Some of the examples mentioned below, even though more costly than some of the type mentioned previously, are equally labour saving, yet may in error be looked upon by many readers as something in the way of a luxury, and probably beyond their means.

Polishing and Buffing Motor.—This type of motor consists of a universal, dust-proof motor, fitted with a double-ended taper

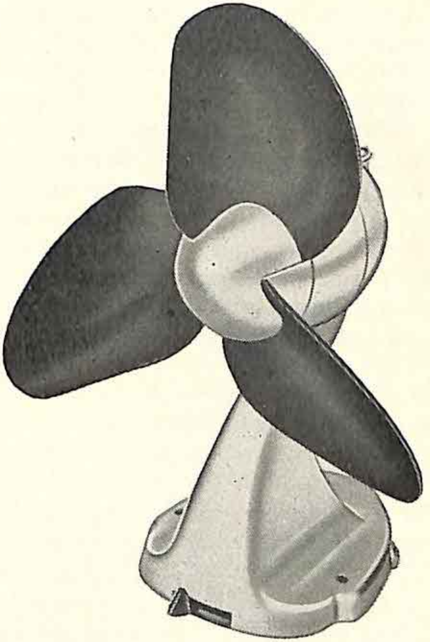


FIG. 122.—A 12 in. rubber-bladed electric fan for table or wall mounting.

spindle rotating at high speed, to which can be attached various forms of polishing pads for cleaning cutlery, silver, electro-plate and many other articles which need polishing. This polishing motor can also be used for cleaning boots and shoes or can be fitted with a grinding wheel for grinding small tools. Although this small type of polisher is not an expensive one, it is not perhaps of sufficient service to justify its purchase in a small household.

Mixers and Beaters.—For the purpose of mixing and beating, a universal motor is again employed, fitted with speed control by means of a series resistance. The motor, mounted on a convenient base, has a special shaft extension running vertically, to which can be attached a variety of fittings to perform operations such as mincing meat, extracting juice, grinding coffee, cracking ice, slicing vegetables, apart from the ordinary work of mixing and beating flour or mixing drinks.

Here again, unless there is sufficient variety of work for this machine to do, its purchase would not be warranted.

Sewing-machine Motors.—The application of an electric drive to sewing machines instead of hand or treadle operation simplifies matters tremendously for the operator, making the work much easier to carry out. Quite a good percentage of small households possess one of the usual hand or treadle-operated machines to which an electric motor can be attached without going to the expense of a new and complete electric sewing machine.

The universal motor supplied for this work is fitted with brackets or attachments to fit all the leading makes of sewing machines. There are two general types of drive, the first being a belt-driven for a motor located under the sewing-machine table, the speed being mechanically controlled by a friction clutch operated by means of a lever connected to the treadle. In the other type of drive the motor is permanently fixed to the frame of the sewing machine, power being transmitted directly to the driving-wheel by a friction pulley on the motor-shaft end. Speed regulation is effected by a variable resistance in the circuit and operated with a foot-switch or controller.

Health Motors.—The application of an electric motor in contributing to one's health is made possible by an appliance known as the electric stimulator. This is an ingenious massage device which affords exercise to muscles, tissues and vital organs of the body. Instruction for their use include a large variety of exercises for men and women, and their effect can be obtained by consulting the sales literature available for these body stimulators.

The motor for this purpose is not universal, but a separate motor for A.C. and another for D.C. By means of special grooved pulleys mounted eccentrically, one at each end of the motor shaft, a vibrating movement is imparted to the belt attached to the two pulleys. By means of the grooves in the pulleys a varied degree of vibration, from a vigorous action to a gentle massage, can be obtained according to the particular exercises. The ball-bearing motor, running at a constant speed of about 950 r.p.m., can be operated from a table or a special pedestal, a safety-switch being incorporated in the base of the motor.

Washing and Wringing Machine. — The labour-saving of electric washing and wringing machines does not require detailing; they save time, work and expense. Perhaps the most popular type of electric washer is known as the agitator

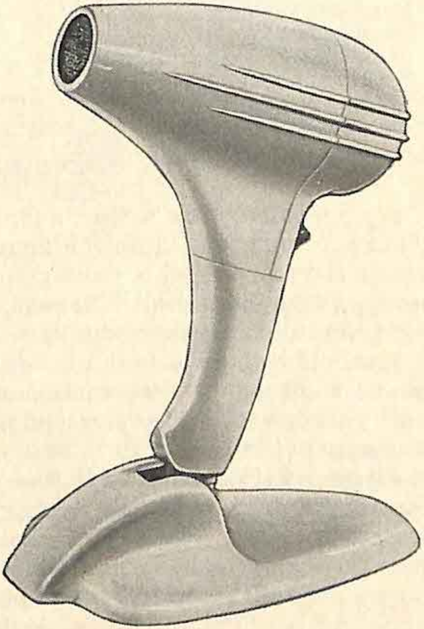


FIG. 123.—An electric hair-drier and stand.

type. In construction this type of washer consists of the usual type of tub mounted to a substantial frame with feet and accommodation for the wringer at the top. At the base of the tub is the agitator, usually in the nature of a metal dolly carrying three or four blades, and so constructed and connected to the motor that it oscillates from fifty to eighty half-turns per minute. The actual power transmission from the motor (which is not universal) may be either belt-drive or direct-shaft drive.

Type.	Approx. H.P.	Watts Consumed.	Hours Running for 1*d*. at 1*d*. per Unit.
Sewing motor . .	$\frac{1}{40}$	50	20
Mixer and beater .	$\frac{1}{15}$	100	10
Polishing motor .	$\frac{1}{8}$	200	5
Stimulator . .	$\frac{1}{6}$	250	4
Washer and wringer .	$\frac{1}{4}$	300	3½
Refrigerator . .	$\frac{1}{6}$	250	10

(See also table on page 165.)

For operation of the wringer a direct drive is taken from the motor separately through a housing at the side of the tub, and equipped with gearing for wringing from the washer to the sink or tub. The wringer may be used either independently or together with the washing action.

It should be noticed in this example of fractional-horse-power motor use that the complete washer and motor frame are earthed, a three-pin plug and three-core cable being necessary in this case.

Electric Refrigeration.—Electrically-operated refrigerators for domestic use are now becoming a standard appliance in the all-electric house. The requirements for the ideal preservation of food is a maintained temperature of 40 to 50 deg., and the air to be dry and pure, and free from dust and dirt. All these conditions are fulfilled by the electric refrigerator.

Refrigeration is the process of cooling, and is based upon the fact that all gases, when subjected to sufficient pressure and cold, become liquefied and liberate their latent heat. Conversely, when the pressure is reduced and the liquid gas evaporates, heat is absorbed from the surroundings, resulting in a lowering of the temperature in those surroundings.

In the refrigerator operated by a fractional-horse-power motor (not universal), the refrigerant usually employed is sulphur dioxide gas, which is subject to pressure in the compressor driven by the motor, and cooled by a current of air produced by a fan, also operated by the motor. This process liquefies the gas, and when passed to the evaporating unit it evaporates, and so absorbs heat from the food-storage chamber in which it is fixed. Following this, the vaporised gas is drawn into the compressor and re-liquefied, these operations being automatically repeated. The motor operating the compressor is either belt-driven or direct-coupled, and is controlled by a thermostat, thus maintaining the pre-determined temperature necessary for the storage—that is to say, the motor is automatically switched off when the temperature falls below 40 deg., and switched on again when the temperature reaches 50 deg.

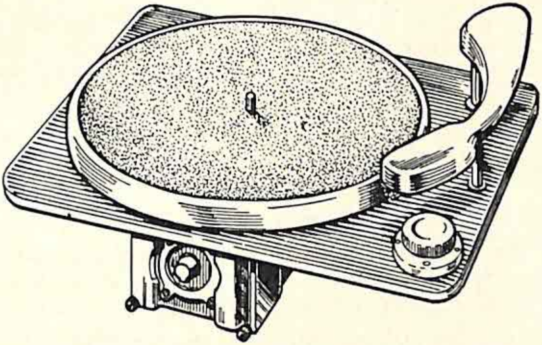


FIG. 124.—A very compact gramophone turntable unit driven by an electric motor.

Remaining examples of fractional-horse-power motors for use in larger establishments include potato peelers, meat, food, vegetable choppers and dish washers.

In the Tables on pp. 165 and 168 are given the consumption of watts, operating hours for one unit, and the approximate horse-power for the motors described above.

Referring to figures for the refrigerator, the ten hours is not the running time of the motor, but the operating hours of the refrigerator, the motor only running intermittently.

XIX

FRACTIONAL-HORSE-POWER A.C. MOTORS

WHILE there is abundant literature available concerning the design and repair of direct-current motors, there appears to be a scarcity of easily assimilable information dealing with motors of the A.C. class.

It is the purpose of this chapter to show the method of locating faults and the correct way of carrying out the necessary repairs. Such calculations as may be necessary are kept as simple as possible, and although the liberties taken with orthodox formulae may offend the mathematician, it must be borne in mind that it is the writer's aim to keep the subject-matter well within the scope of the amateur.

Before dealing with the question of re-winding a broken-down motor, it would be as well to give a brief description of each of the more commonly encountered types of A.C. motor, so that the reader will have no difficulty in recognising the class to which his motor belongs and can accordingly understand the correct method of arranging and connecting the wiring.

A.C. motors are usually classed according to their methods of starting, variations of which in recent years have been rapidly developed, so that these motors compare very favourably as regards ease of starting with the older and more familiar direct current motor.

The chart, Fig. 125, conveniently summarises the main types of A.C. motor and their variations.

The Induction Motor.—The characteristics and general construction of all induction motors, irrespective of their methods of starting, are fundamentally the same. The rotor, or, as its name implies, the revolving part of the motor, consists simply of a number of laminated iron stampings separated by insulating material and secured round the periphery by a number of aluminium bars, the latter being short-circuited at each end by heavy metal end rings. This part is practically indestructible, and it is unlikely that any fault will be traced to this section of the motor. The stator or external member is of similar construction to the rotor, except that in the place of the copper bars and their short-circuiting end rings, coils are grouped round the inner periphery, being arranged in slots cut in the iron stampings. There is a variation of this motor known as the "inverted-rotor" type which is sometimes met with; in this design the coils are carried on the rotor, while the stator bears the copper rods and end rings; the principle is exactly the same, except that the position of the rotor and stator are reversed.

Induction motors are constant-speed motors, the speed in all cases being a definite function of the frequency of the supply. For instance, if the supply alternates 50 times a second or 3,000 times a minute, the speed of a two-pole motor would be 3,000 r.p.m., while a four-pole motor would revolve at half this speed, and a six-pole motor would have one-third or 1,000 r.p.m. Intermediate speeds are unobtainable, as the speeds must always bear a whole number ratio to the frequency of the supply. These speeds are, of course, theoretical, as there is a slight drop in speed on load, which, however, never amounts to more than about 5 per cent. of the free running speed.

The Split-phase-start Motor.—This type is the earliest and simplest of all induction motors; its freedom from mechanical breakdowns, and its robust construction generally makes this an ideal type for household and similar purposes. Its only drawbacks are a low starting torque which, on modern designs, amounts to about twice full-load torque, and an excessive starting current, which amounts to nearly four times that required when running.

The connection scheme of the starting and running windings is shown in Fig. 126. The starting windings are usually wound on top of the main windings; the coils, however, are displaced one-half pole pitch to the main coils. This gives rise to secondary poles, which, coming into operation either earlier or later than the main poles, create a phase lag which drags the rotor round in a definite direction.

When the motor has accelerated, the starting windings are cut out of the circuit by means of either an external manually operated switch or, in the case of more modern designs, by an automatic centrifugal switch which is attached to the spindle of the motor itself and comes into operation at a predetermined speed.

The Capacitor Motor.—This type is yet another variation of the split-phase-start type of motor, and differs only in its method of starting. There are two types of capacitor motors in use: the "capacitor-start" motor and the "capacitor-start-run"; the former has a condenser introduced into the circuit in series with the starting winding, and which is cut out together with the starting winding when the motor has run up to speed, the latter has a small transformer in addition to the condenser, both in this type being left permanently in the circuit, an automatic centrifugal switch changing to transformer tappings when the motor has accelerated. The connection arrangement of the main and auxiliary coils in relation to the condenser and transformer is shown in Fig. 127. This type of motor is virtually a two-phase motor and has all the starting advantages of such a motor and is undoubtedly a great improvement on the simple split-phase type.

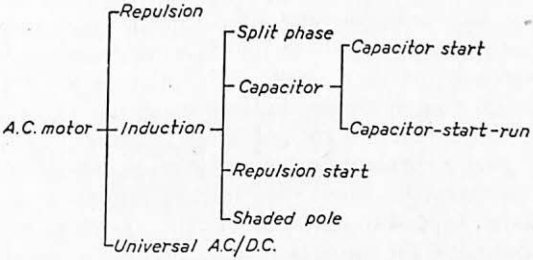


FIG. 125.—This chart summarises the main types of A.C. motors and their variations.

The Repulsion-start Motor.—This type of motor is a combination of the repulsion motor and the ordinary

TABLE OF EFFICIENCIES.	
$\frac{1}{16}$ to $\frac{1}{10}$ h.p.	45 per cent
$\frac{1}{8}$ to $\frac{1}{6}$ h.p.	50 per cent
$\frac{1}{4}$ to $\frac{1}{2}$ h.p.	60 per cent
$\frac{3}{4}$ to 1 h.p.	70 per cent

squirrel-cage induction motor. The principle of the repulsion motor is employed at starting, but at a predetermined speed the commutator bars are short-circuited and the motor runs as an ordinary squirrel-cage motor.

The Shaded-pole Motor.—A brief description of this type of motor will complete the four variations of induction motor set out in the chart in Fig. 125. Although very little used except in the very small sizes, this type is of a quite reliable and simple design, but unfortunately the very low starting torque exerted by this motor makes it unsuitable for any purpose except perhaps for driving small fans and similar apparatus, where no starting effort is required beyond that needed to overcome the friction of the bearings.

The design of the stator is of the usual type except that no starting coils are used, each pole being unequally divided by a copper strip which causes a time-lag between the magnetisation of the two unequal surfaces, thereby setting up a sliding flux across the surface of the poles which drags the rotor round in a definite direction.

The Universal A.C./D.C. Motor.—No useful purpose will be served by giving here a full description of this type of motor, as it is simply a series-wound D.C. motor, and any textbook on the subject will give a full description of its design and characteristics. Reference to the Table of Efficiencies given above will enable you to make your choice.

The Repulsion Motor.—The repulsion type of motor, the connection scheme of

TABLE OF WIRE GAUGES.

S.W.G.	Current.
25	0·942
24	1·140
23	1·356
22	1·848
21	2·412
20	3·064
19	3·771
18	5·430

which is shown in Fig. 128, is similar to the universal type (Fig. 129) except that instead of having the coils grouped on projecting poles, they are distributed in slots all round the periphery. The connection arrangement is also different, in that the brushes are short-circuited together and the current is supplied to the field windings only.

There is a further class of motor known as the "synchronous" motor, but reference to this type is omitted, as they are rarely met with in such small sizes.

Rewinding.—Let it be assumed for the purpose of explanation that the motor to be rewound is rated at ¼-h.p. and is intended for use on a 200-volt 50-cycle supply at a speed of approximately 1,500 r.p.m. If the following calculations are carefully worked out, no difficulty should be experienced in applying the same method in carrying out the same calculations for any other size of A.C. motor under 1-h.p.

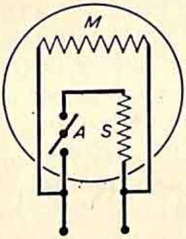
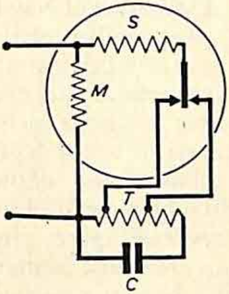


Fig. 126.—(*Left*) The connection scheme of starting and running windings of a split-phase-start motor.

Fig. 127.—(*Right*) The connection arrangement of the main and auxiliary coils in relation to the condenser and transformer of a capacitor motor.



The first step before proceeding with rewinding is to find by calculation the correct size of wire necessary to carry the current absorbed by the motor. In order to do this the current consumption must first be found. Bearing in mind that 1-h.p. = 746 watts, and referring to the Table of Efficiencies given on p. 174, the input in watts is arrived at by multiplying the output watts (which for the motor in question would be 746 divided by 4) by 100, and dividing the product by the efficiency. The table gives the efficiency as 60 per cent., thus the input watts would be:

$$\frac{746 \times 100}{4 \times 60} = 310 \text{ watts.}$$

To find the current consumption from the above figure it is now necessary to divide by the voltage and correct for power factor, which for small motors may be taken as 0·6 thus:

$$\frac{310}{200 \times 0{\cdot}6} = 2{\cdot}6 \text{ amps.}$$

Reference to the Wire Table (p. 174) will now give the nearest size of wire suitable for carrying a current of 2·6 amps. as being No. 21 S.W.G.

Estimation of Number of Turns.—The first step in arriving at the number of turns necessary for the main windings consists in calculating the flux per pole. In order to do this, it is necessary to find the area of the inner surface of the stator in square inches by multiplying the circumference of the stator by the depth. Let it be assumed for the purpose of explaining the following calculations that the stator has a circumference of 9 in. and a depth of 2 in. The product of these two figures gives the total area in square inches. As this area must be shared by outgoing and incoming magnetic flux lines, the magnetic pole section must be taken at half this figure, which is still further reduced by multiplying by the factor 0·5 to allow for loss of iron through the slot spaces. The working area would thus be:

$$\frac{9 \times 2}{9 \times 2} = 4{\cdot}5 \text{ sq. in.}$$

The area thus obtained must now be divided by the number of poles and multiplied by a figure denoting the flux density; this latter value may be taken as an all-round figure of 35,000 for any size of motor under 1-h.p. As previously stated, a motor running at 1,500 r.p.m. must have four poles on the stator, thus the flux per pole of the motor under consideration would be:

$$\frac{35{,}000 \times 4{\cdot}5}{4} = 39{,}375 \text{ lines per pole.}$$

The total number of turns can now be ascertained from the following formula:

$$\text{Turns} = \frac{E \times 10}{\phi \times F \times 4}$$

where E stands for the voltage of the supply, ϕ the flux per pole and F the frequency.

Substituting the calculated flux per pole and the other known data in the above formula, we get:

$$\text{Turns} = \frac{200 \times 100{,}000{,}000}{39{,}375 \times 50 \times 4} = 2{,}539.$$

This figure must be further divided by the number of poles, which brings the number of turns per pole to 635.

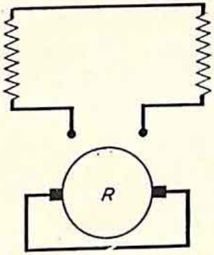


FIG. 128.—(*Left*) A repulsion type of motor.

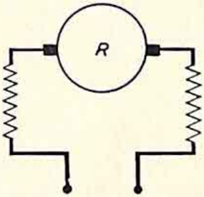


FIG. 129.—(*Right*) The connection scheme of a universal motor.

Arrangement of Coils.—Assuming the stator of the motor under consideration to have twenty-four slots—which is the usual number for a motor of this size—it is obvious that, as each coil occupies two slots, twelve coils will be required. Thus the turns per coil will be:

$$\frac{635}{12} = 53 \text{ turns.}$$

Having arrived at this figure, and knowing the gauge of wire to be used, the actual winding can now be undertaken. No particular difficulty attaches to this part of the work, but care must be taken that the windings are kept as compact as possible, otherwise there will not be sufficient room left for the starting windings which follow the main windings. These latter are wound over the main windings, but are displaced one-half pole pitch, so that starting will be possible in either direction. No calculations of a complicated nature are necessary in estimating the turns and gauge of wire for the starting coils. A perfectly safe plan to follow is to use wire of five gauges smaller than that used for the main winding, and to wind each of the twelve coils with from one-half to two-thirds of the number of turns used on the main coils. All coils are connected in series, and the connections between the main and starting coils should be arranged as previously indicated.

In conclusion, it may be pointed out that the above method of calculating turns and sizes of wire can be adapted to any size of A.C. motor under 1-h.p., and that the principles underlying the calculations are the same, whatever the type of motor, the only differences being in the connections between the coils and starting gear, full details of which have already been given.

XX

REPAIRING ELECTRICAL APPARATUS

THE peak voltage on A.C. is voltage multiplied by the square root of 2—or voltage × 1·414. With 230v. A.C. this will be 300. If you keep this point in mind you will avoid shocks. When making an examination of any apparatus, always disconnect from the supply, either by removing the plug or switching off at the mains. If you are doing any work on an installation, such as changing a fitting or plug, or anything connected with the permanent wiring, then switch off at the mains and pull the fuses. This is the only way to make certain that someone will not come along and switch on again.

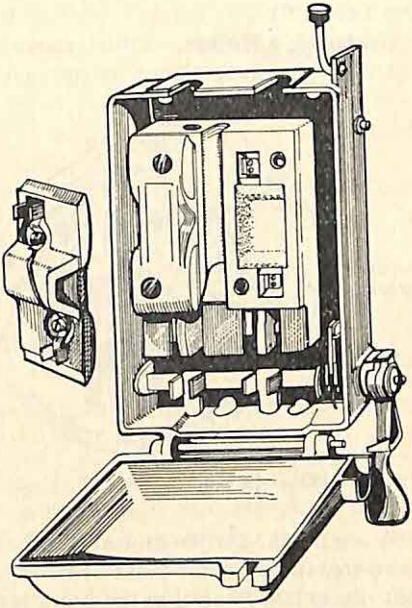


FIG. 130.—A fuse-box and fuses.

The Main Fuse.—I will start with the point of entrance of the cable and follow it to the various points dealing with the possible faults as they arise. If a main fuse blows, you cannot replace it, but must notify the supply company, who will send a man to do it. The main fuse-box is sealed, and it is an offence to break this. If a main goes, there must be some serious fault in the circuit.

Replacing Local Fuse.—If a local fuse blows, first find the reason. There is always a reason and a very good one. Generally, it is an overload on the circuit, although it may be some accidental short, worn flexes or cut wires. Remedy this and replace the fuse with the correct size of fuse-wire. It is usual to employ 5-amp. wire for lighting circuits, and 10 or 15 for power. Switch off the mains, remove the fuse carrier, clean off all carbon and fused wires, put on the new wire and replace. Switch on. Remember to remove all the old wire. Make certain of good connections at the fuse clips (see Fig. 130).

Replacing a Switch.—Often a switch may need replacing, especially in such places as garages and workrooms, etc. First obtain a good switch of the same type and pattern—i.e., 5- or 10-amp. sunk or surface mounting, etc. (see Fig. 131). Switch off at the main and pull the fuses. Now slacken the connecting screws on the switch, remove the fixing screws, pull out the switch and then put on the new one. Take care to mount this the right way up and to put the wires on the same sides as before. It is quite possible to put the switch in so that the knob is down and the light off. Do not throw away the old switch—it may be kept as a useful spare for future repairs. The cover and terminal and the action spring can be removed and put into broken switches. You may not think this worth while, but the repairing of a switch is quite intricate and interesting work, and the procedure is as follows. To "open up" remove the sealing-wax from the heads of the screws at the back, undo these and the dolly will pull out. It may leave the movable

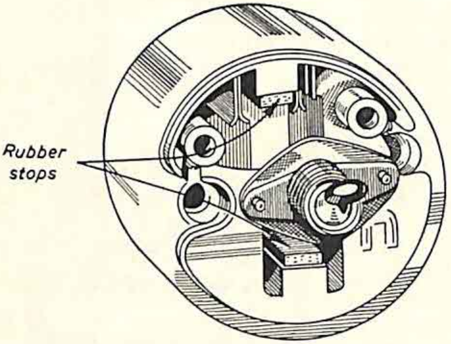


FIG. 131.—An efficient type of switch.

contacts behind. If not, a slight pull will remove them, exposing the action spring. You now have the switch in pieces, and it is easy, if you have a spare, to replace a broken part. Contacts may be tightened up by judicious pressure with the blade of a screwdriver. Always use good quality switches. It should not be possible to hold the contacts either just in or just out so that arcing occurs. The switch should open and close quickly with a snap, except in the case of the new silent switches for hospital work. Here the action is barely audible (see Fig. 132).

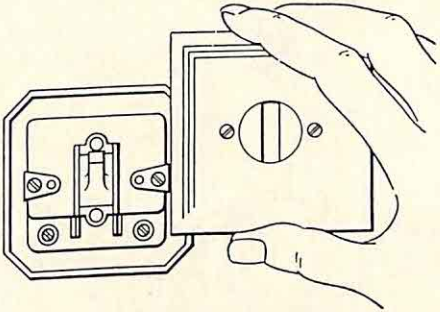


FIG. 132.—This type of switch fits flush to the wall.

The Distribution Point.—Flex often gets worn and frayed when the lamp swings in a draught or when a portable appliance is used at that point. If you are doubtful about the condition of a flex, replace it—the cost is negligible. In the case of large and powerful lamps, the heat will cause the insulation to perish, and finally the rubber cracks away, causing a short or the holder to become "live". Never remove or replace a lamp with the switch on. When replacing a flex, switch off at the mains and remove the fuses. Unscrew the cover of the ceiling rose and disconnect the flex. Now, in a more comfortable position, examine the holder. If the springs in the contacts are quite good, it may be replaced on a new length of flex. Slip the rose cover on the flex, climb the steps and connect up. Make sure that the weight of the flex and fitting is taken by the little hooks or projections on the rose base, and screw back the cover (see Fig. 133).

A word on using portable appliances from light points. The flex and holder are rated at 5 amps. You should not use anything taking more than 500 watts from a holder. All portable apparatus should be earthed. It cannot be earthed if used from the ordinary holder. Yet, you may say, why are irons, fires and vacuum cleaners all sold with adapters for use on the light. This, of course, is to give them a universal appeal. Fig. 134 shows how easy it is to get a shock from a two-pin point of, say a fire or iron. In my opinion, the iron should not be used from the lamp-holder. The housewife is there with damp hands in the kitchen ironing, in easy reach of gas- and water-taps and earthed ironwork. A fault develops in the iron. With one hand she touches the water tap, and a very bad shock results. The same can happen with open fires of the bowl type. Also, with two-pin plugs and fires with switches incorporated, it is possible for the switches to be off and the plug in and yet the element "live". If you wish to test all these statements, get a lamp-holder and flex with crocodile clips as leads, and use this as your subject or patient. Connect one lead to earth and the other to the iron or fire, as above. There is a short if the lamp lights. Wherever possible, use only lamps at the lamp-holders and the proper apparatus at the two-pin point. These points are designed for use with reading lamps and wireless sets which, theoretically, may not require earthing (see Fig. 135).

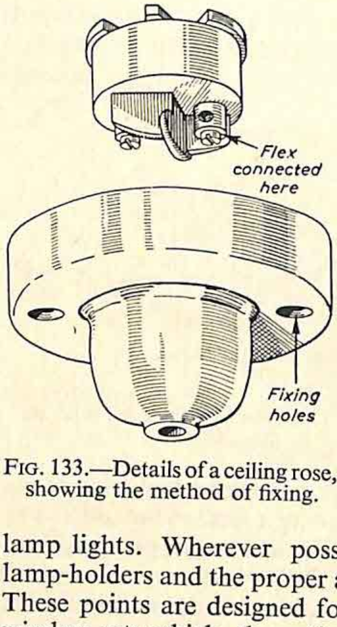


FIG. 133.—Details of a ceiling rose, showing the method of fixing.

The Power Point.—This has an earth pin, which must be used. You may feel tempted to connect up the iron to the plug with the original twin flex. Don't; it is safer to get a good-quality triple cable, and the extra safety will well repay the outlay. Braided cable has a nasty habit of fraying at the adapter and then shorting. The wires in the cable each have their own colour, so that it is an easy matter to earth the correct one. Some iron adaptors have a small spring tongue that touches the metal case of the iron. This is the earth contact. Bend it out so that it makes good contact. The same general remarks apply to frayed cables, etc., but one must use the cable of the correct size for the appliance. If you are using a 3-kilowatt fire from a plug, do not wire up with lighting flex. Use the correct cable (this is generally supplied with the appliance). On the other hand, if you are using a 750-watt fire from a 15-amp. point, thinner flex can be used, but to protect the circuit the 15-amp. fuse must be replaced with a 5-amp. one. This is very important, because the earth might burn before the fuse blows if a fault develops in the fire. Fig. 135 shows a socket from which any apparatus may be used with safety.

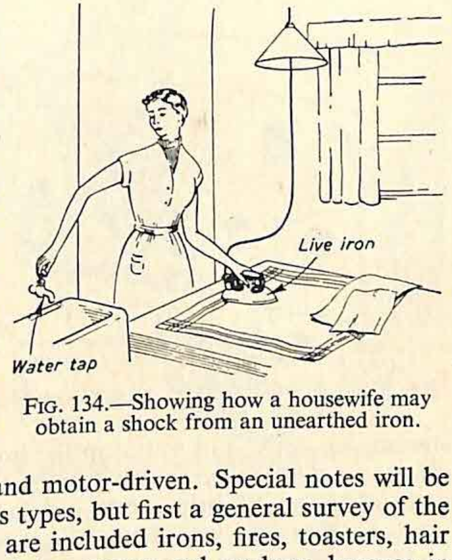


FIG. 134.—Showing how a housewife may obtain a shock from an unearthed iron.

Two Types.—All domestic appliances can be divided into two types, heating and motor-driven. Special notes will be given for the various types, but first a general survey of the heating type. Here are included irons, fires, toasters, hair driers, kettles, hot plates, stoves and cookers, because in each case the element is a length of wire that becomes hot when in use. A group of appliances is shown in Fig. 136. A combination of the two types is found in modern fires and hair driers, etc. Nowadays all heating elements are standard —i.e., if your iron burns out, a new element can be bought from the makers. The sketch (Fig. 137) shows a dismantled iron; we will deal with fitting a new element first. Remove the cable connector. The shell is fixed to the base by two domed nuts, *A* and *B*. Unscrew these and gently lift the cover off. In some types connection is made by two springs from the adapter to the element; in others it is a strip of metal. If by springs, the cover comes straight off; if by strips, unscrew these at the connector. The element is clamped to the base by a heavy iron stop, and may now be removed. The element is wound on a mica former and is completely insulated from the frame. When removed, take it to your testing bench and connect in series with a lamp. If it lights, then the element is not at fault and the connector must be to blame. A faulty element can generally be spotted by holding up to the light; the burnt spot shows as a black dot. Do not attempt to repair an element, but put in a new one; lay it flat on the plate, put on the iron weight and the cover and tighten up the nuts. Make sure that the springs touch the element correctly, and warm up the iron. When hot, disconnect and put another half-turn on the clamping nuts.

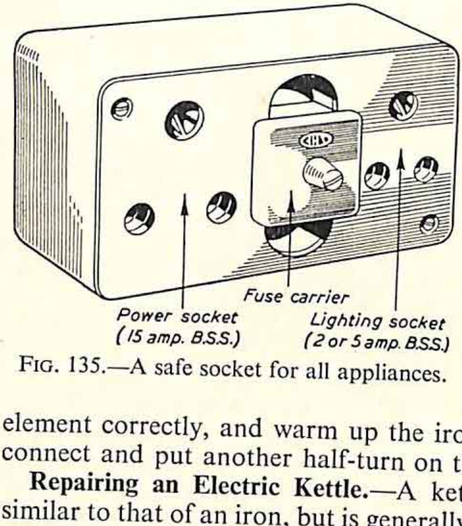


FIG. 135.—A safe socket for all appliances.

Repairing an Electric Kettle.—A kettle element is very similar to that of an iron, but is generally in two halves. The replacing of the element is carried out in the same way. First invert the kettle, then remove the cover-plate exposing the elements. These are clamped under a thick copper disc by one screw passing through the centre. Remove this and the elements. Connections are made through copper flexibles insulated with porcelain beads. Preserve these, as they must be put back on the new element. Observe the position of the old element and replace the new one in exactly the same way. Connect up as before. Most kettles, sterilisers and similar appliances are fitted with a cut-out (see Fig. 138) that opens the circuit when the vessel boils dry. Some have a small fusible capsule, which has to be replaced each time it boils dry. The commonest method, which is found on all good-class apparatus, is the bimetal thermostat. The actual design varies with the maker, but the principle is the same. A bimetal strip forms part of the circuit, and when this is overheated it bends outwards and opens the circuit. Any repairs here consist of cleaning the contacts and perhaps bending the strip slightly so that a good contact is made. The contacts can be reset by a knob on the base of the kettle, and need not be touched in the ordinary way.

FIG. 136.—A group of "heater" appliances.

Electric fires, toasters, etc., are the easiest to repair, because the elements are exposed and very accessible. In the bowl type of fire the element is protected by a small wire guard clipped over the edge of the bowl and easily removed. Unscrew the element and former. This is a fire-brick former fitted with a G.E.S. cup. It often happens that the centre contact of the holder becomes weak through over-heating. Arcing occurs here, with the result that the fire burns intermittently and finally goes out altogether. The contact can be replaced by a strip cut from the longer pole of a flash-lamp battery. Make this exactly the same size as the original, or it may touch the edges and cause a short.

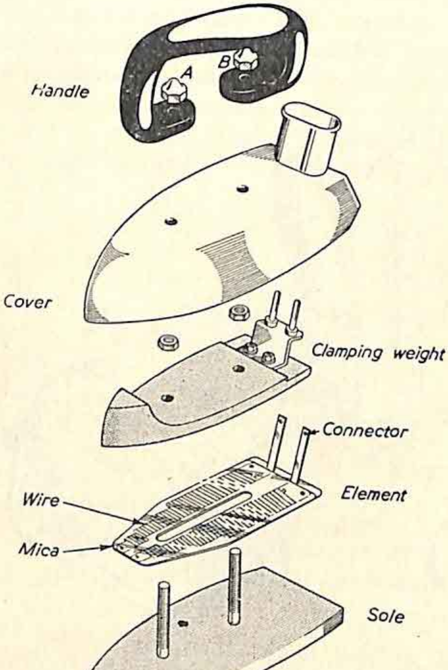


FIG. 137.—An exploded view of an electric iron.

If the element has burnt out this is obvious because the spiral will be slack and broken. Each spiral is wound for a definite voltage. Do not cut the spiral, but pull it out to the required length by trial. One connector is made first and the wire pulled out to fill the grooves, and then joined to the other screw. Slight tension only should be felt in the spiral when both ends are connected. To make a connection double over one end of the wire and hoist it up tightly, then pass this round the screw between the two washers and tighten up. If a contact becomes loose the wire will arc here and finally burn through, and once an element has broken after being in use it cannot be rejoined. The wire becomes brittle and breaks when bent. Screw back the former tightly before switching on.

Elements.—A similar small spiral element is found in toasters, but here the spiral is arranged in rows vertically. Attachments and replacements are made as before. In the hair-drier the element is wound on a light former of mica. It is of single wire. To examine the element remove the cap at the end of the air tube and then pull the element out. The former is plugged into a holder in the base. An element easily burns out when the fan fails, so before replacing the element in a drier in which the fan has failed repair the fan first, then the element.

The bowl fire is rarely found with loadings over 1,000 watts (see Fig. 139). When replacing broken elements in larger fires remove the old former and wire by disconnecting at each end and replace with a new one. When ordering spares quote the fire make and type, the loading in kilowatts and the line voltage. There is a type of fire with two spiral elements wound on flat fire-brick formers, each of a loading of 750 watts. Either one or both may be used, depending on the switching arrangements. A further type has for the element a carborundum rod of special manufacture. Replacements are very easy but fairly expensive. In furnaces two rods are generally used in series, and it is advised that when replacing to replace both, because two old rods may be used together, but not one old and one new. If a controlling resistance is used in series with the furnace any combination may be used, providing that the furnace is allowed to heat up slowly. This effects quite a saving, as the rods are expensive.

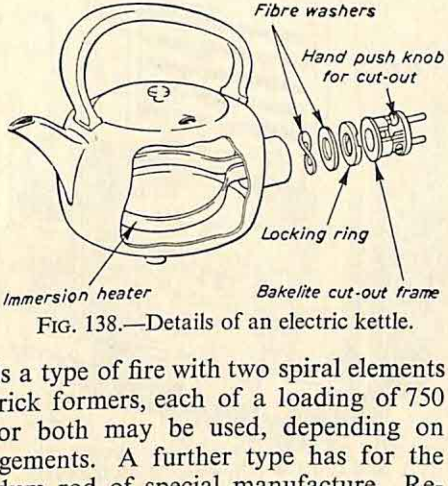


FIG. 138.—Details of an electric kettle.

Fans, Hot-plates, etc.—Most modern fires (Fig. 140) have a supplementary lamp to cause the "glow", and the flicker is caused by a small fan revolving above the lamp. This fan is really a two-bladed shutter that revolves in the hot air rising from the lamp. If the fire receives a blow, the fan may jam or come off its pivot, but it is easily replaced. Do not lubricate the fan, but a little blacklead—a few strokes with a B.B. pencil—on the pivot will be found effective.

Hot-plates are rewound in the same way as toasters and bowl fires. Some hot-plates have a concealed and embedded winding (Fig. 141), but these cannot be repaired at home, and must be returned to the maker.

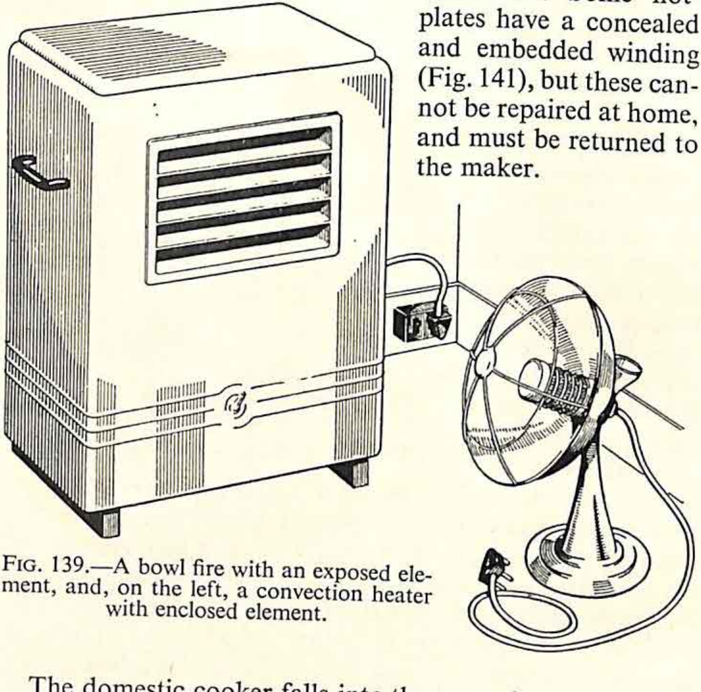


FIG. 139.—A bowl fire with an exposed element, and, on the left, a convection heater with enclosed element.

The domestic cooker falls into the same class as fires, but there are several points that may go wrong. Elements can burn out, but replacements may be obtained easily and fitted just as a fire element. A cooker is a piece of high-load apparatus, and as a result the switches are quite large and, due to the arrangement of the elements, complicated (Figs. 142 and 143).

These switches are of the rotary type, generally having either two or three positions and "off". Switch failure is usually due to burning of the contacts, with consequent arcing and, finally, open circuit on some points. The contact blades cannot be replaced, so a new switch is required. Disconnect the leads, but do not disturb their relative positions; there may be four, five or six terminals on the switch, with as many as twelve leads connected to them, hence care is necessary. If you are in doubt, before removing any collection of leads tie together and label. Take care to avoid crossing the leads.

Some fires and heaters have a very nasty habit of humming, like a transformer, but with a noise that is louder and more penetrating. If an old fire starts this, then it is generally due to a loose connection, or even a loose bolt on the fire-case. Tighten up all nuts and bolts and connections. If a new fire does it, look for the possible loose connection or bolt, but, failing to find one, you are advised to change the fire.

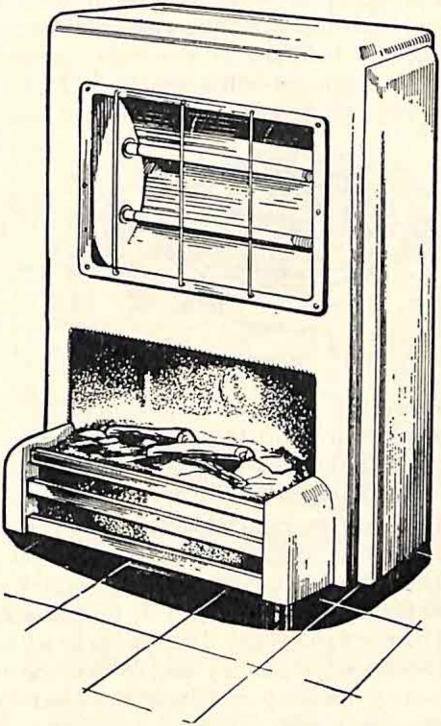


FIG. 140.—A flickering "coal" fire with two heater elements.

So far I have only mentioned the all-important question of earthing, and not given it the importance it deserves. I cannot over-estimate the importance of a good earth on all portable appliances, especially those near water-pipes, etc. Some appliances are not provided with an earth connection, but one can easily be made. If a fire is required to be earthed, drill a $\frac{1}{4}$-in. hole in the case, push through it a $\frac{3}{16}$-in. bolt, put on two large washers and clamp the earth wire tightly between. An iron may be earthed by passing a lead under one of the cover securing nuts. A hair-drier, if made of bakelite, need not be earthed, but must have a metal sleeve or other heater, and the earth wire may be passed under one of the screws securing it. All fixed apparatus, such as cookers, fires, etc., will be earthed, but periodically examine them. The earth must be capable of carrying the maximum load of the appliance. It is possible for a few strands of an earth to corrode through and yet the appliance be earthed, but it is not safe, because the cable could fuse at the weak spot and leave the cooker "live". The same can apply to fires. The earth wire is often regarded by the layman as being quite unnecessary and put on for fun. The regulations say that the earth wire must be protected if necessary. This may not be necessary when the appliance is first installed, but later the need for an earth becomes apparent.

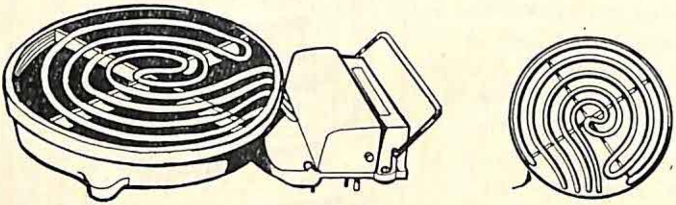


FIG. 141.—(*Left*) A hot plate. (*Right*) A four-heat boiling plate.

Domestic Motors.—Domestic motors are generally of one main type—series commutator. Others in use are repulsion-induction and squirrel cage; but fortunately repairs in these are rarely if ever necessary because there are no electrical moving parts to wear.

Running repairs consist of oiling and greasing and cleaning the commutator. This work is easy, and does not need the dismantling of the machine.

With commutator machines, and especially those small ones that are frequently overloaded, the brushes require constant care and attention. Sparking is always present; it is not necessarily a bad sign, but when the sparks extend right round the commutator, stop the machine and examine. New brushes are fitted by lifting the tension springs and extracting the old ones. Fit brushes of exactly the same type. Never be tempted to file up any scrap carbon, and use this as a brush. It will damage the commutator and cause excessive sparking. This method may be used in cases of emergency, but replace the makeshift brush by the correct one as soon as possible. The brush position in some machines is often obscure, and it is sometimes necessary to dismantle the covers and cases on vacuum cleaners and hair-driers, etc. The replacing of a brush spring is quite easy. First draw out the brush and then make a new spring from stiff brass wire of a similar gauge.

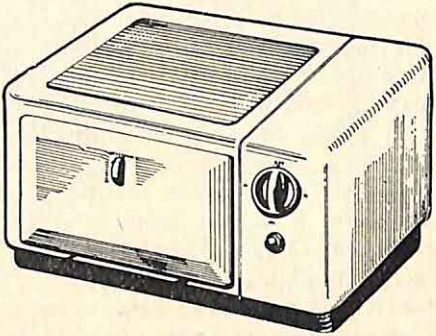


FIG. 142.—A small electric cooker, showing the rotary switch.

Commutators must be cleaned with soft rags. Do not try to smooth down with sand-paper or emery cloth. If a commutator is badly fitted and worn, it must be repaired by an expert. If a machine is over-oiled and oil gets on the commutator, this must be cleaned and dried. It may be necessary to separate the bars and remove carbon. Do this with a pin or needle, and smooth down the rough edges with a steel burnisher. Too much grease is as bad as too much oil, and if this gets on to the winding it may cause, like oil, a short or a fire.

A "Burn-out".—In the case of a burn-out of either armature or field, carefully dismantle and inspect all connections. Examine and test both armatures and field to discover in which the connection has gone. It will probably be the field, so carefully remove one coil and strip off the insulation tape. Now take a sample of the wire and find out its gauge. If you do not possess a micrometer, take a sample with you to the shop when you get the new supply. Count the number of turns; there will be the same amount of wire on each pole, but as an additional check, examine the other pole as well. Weigh the total amount of wire and obtain slightly more than this from the suppliers. Rewinding is now a simple matter. Take the usual care with insulation and other problems.

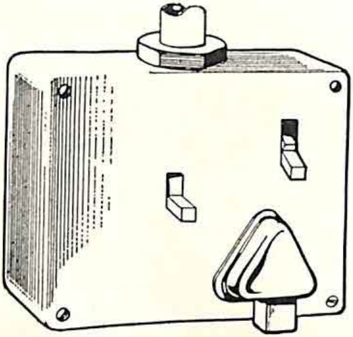


FIG. 143.—A modern cooker control switch.

If the trouble lies in the armature, it is not easily remedied. You will be able to tell, as a burnt-out armature is always obvious. Strip one coil and very carefully note the connections. Draw these on paper, and pin the paper on the wall over your bench. If you pick a coil that will not unwind, leave it and examine the armature closely until you find the coil that was put on last, then start from this and count the number of turns. Weigh the total amount of wire. When dismantling keep count of the turns on each coil, as they should be the same. Observe the relation of the slot to the commutator segment and the brush line to the inter-pole line. Find the gauge of wire on the armature and obtain new as before.

New Insulations.—New insulations must be used on both the armature and field, and these must be identical with those removed. If the insulation is thicker, the correct number of turns cannot be put in each slot. It is essential that exactly the same amount of wire is put on each coil, in order to balance the armature both electrically and mechanically. Unevenly wound coils cause excessive sparking and noisy running. Great care must be exercised in soldering the connections to the commutator bars, and a non-corrosive flux must be used. This method of rewinding by counting the original turns is superior to a purely theoretical one based on calculations, etc. I advise readers to use the above, even when the windings are charred and burnt quite badly. Most insulation is double cotton, and if this is used in all cases it will suffice.

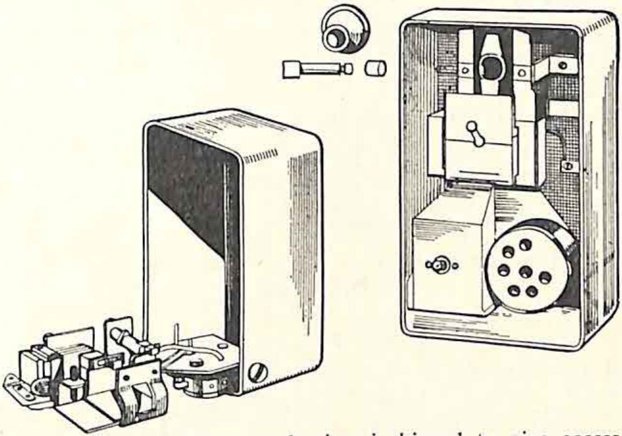


FIG. 143 *A*.—(*Below*) The mechanism is hinged to give access to the terminals. (*Right*) The switch open showing the construction and connections.

Rewinding Heater Elements.—Readers may wonder why I have not given details for rewinding heater elements for fires, etc. The chief reason is that manufacturers will not supply small quantities of these wires. A pound reel is generally the smallest, and this is too expensive for the average reader. Secondly, elements are all standard now and can be obtained from the makers quite cheaply, and at these low prices it is not worth while making them. Thirdly, mica of sufficient size and quality is difficult to obtain. When one considers the above, it is obviously not worth while to consider rewinding an element.

XXI

ACCUMULATOR CHARGING

CHARGING from A.C. and D.C. Mains.—The subject of accumulator charging is a very interesting one from the point of view of the amateur who wishes to keep his wireless batteries in good condition and of the electrician operating a service station. Although the principles involved are just the same, whether it is desired to charge a single 2-volt cell at 0·5 amp. or to charge half a dozen car batteries at 8 amps., the practical details of the charger are vastly different in the two cases. In order to cover both classes of work, it will be best to begin by dealing with the points of similarity, and then later on circuits for both kinds of work can be given, along with information concerning their construction and use.

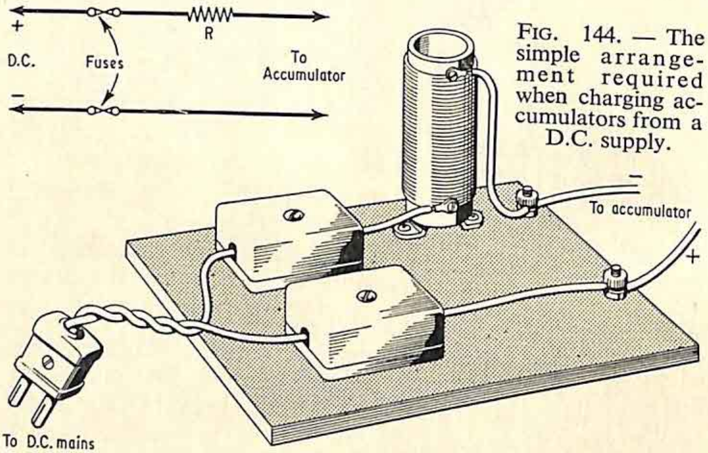


FIG. 144. — The simple arrangement required when charging accumulators from a D.C. supply.

Charging Voltage and Current.—The fundamental point in charging any type of accumulator is that a supply of D.C. must be available. This current can be taken directly from D.C. mains, it can be generated by means of a suitable dynamo and motor (electric, gas or petrol, whichever may be most convenient), or it can be obtained from an A.C. mains supply via a transformer and rectifier through a converter. In all cases the charging voltage (D.C.) must be greater than the nominal voltage of the accumulators to be dealt with; the appropriate voltage is 2·7 per 2-volt cell. For example, if three 2-volt cells are to be charged, a D.C. voltage of 8·1 must be provided. If the voltage were less than that of the cells on charge (and their voltage might rise to something like 2·4, whilst the charging current is being applied), there would be every chance of the batteries and the charging apparatus being damaged, due to a "reverse" current flow being set up.

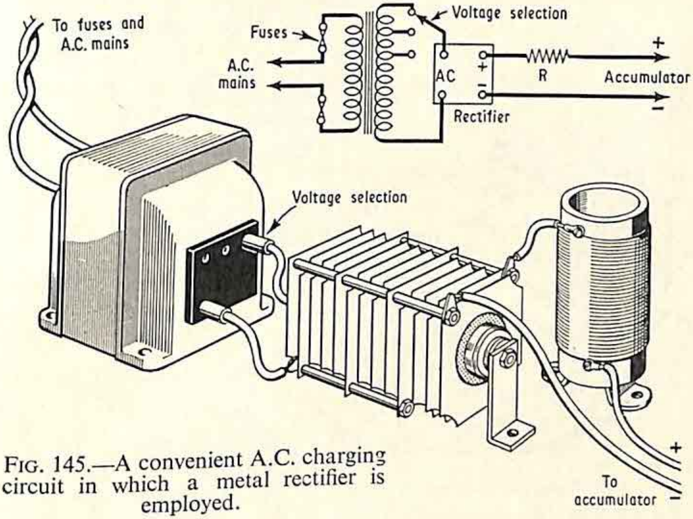


FIG. 145.—A convenient A.C. charging circuit in which a metal rectifier is employed.

The next thing to consider is the charging current, and this depends principally on the ampère-hour capacity of the accumulators being treated. It can be taken as a general rule that the optimum charging current for average accumulators in normal condition should be not more than one-tenth of their ampère-hour capacity. Thus, when charging 30 ampère-hour accumulators, the charging current should be 3 amps. There is no harm in charging at a lower current, but a higher one may be harmful to the plates. When a number of batteries are to be charged together it is unlikely that they will all be of the same capacity, and therefore the charging current should be regulated to suit the smallest.

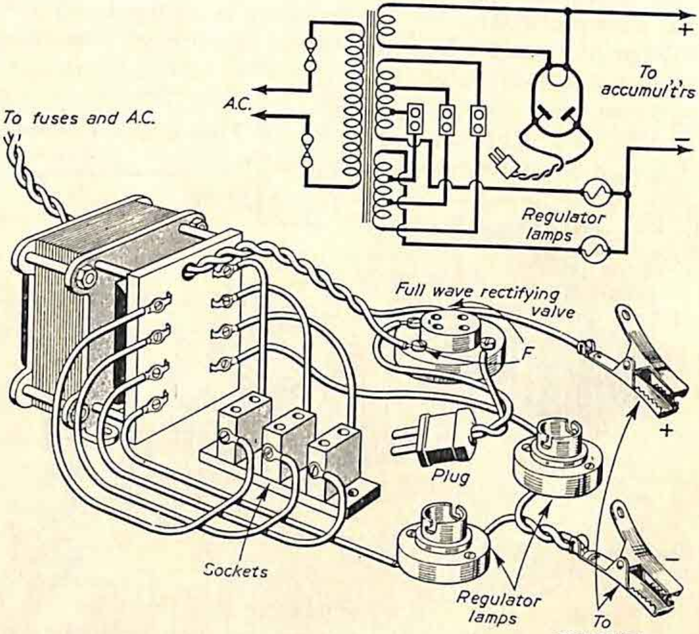


FIG. 146.—An excellent A.C. charging circuit in which regulator lamps are used to maintain a uniform charging current, provision being made to obtain alternative charging voltages.

Charging from D.C.—When charging from D.C. mains the very minimum of apparatus is required, and the circuit is that shown in Fig. 144. It will be seen that the mains leads feed the batteries through two fuses and a resistance marked *R*. The latter may be an ordinary electric lamp when the charging current is no more than 0·5 amp. or so; when the current is up to about 1 amp. a carbon filament lamp can be employed; for higher currents still two or more carbon filament lamps can be joined in parallel, a special regulator lamp can be employed, or the resistance might be one of the wire-wound variety made by connecting air-spaced coils of eureka resistance wire in series. If lamps are to be used, the current which any particular one will pass can easily be calculated by dividing the rated wattage of the lamp by its marked voltage. Thus, a 100-watt, 200-volt lamp will pass 100 divided by 200, or ½ amp. The current could be doubled by putting two lamps in parallel, or trebled by using three in parallel, and so on.

When there is only a single 2- or 4-volt cell to be trickle charged (charged at a low rate, say up to 0·5 amp.), it is often possible to charge it from D.C. simply by wiring it in series with an ordinary light, electric fire or other device. With such an arrangement the charging costs nothing, and the efficiency of the light or appliance is reduced only very slightly.

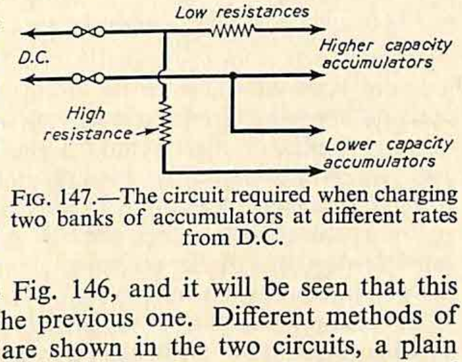


FIG. 147.—The circuit required when charging two banks of accumulators at different rates from D.C.

Circuits for A.C.—Charging from A.C. is rather a different matter, due to the fact that a transformer and rectifier are called for. A suitable circuit for charging up to three cells (6 volts) at 2 amps. is given in Fig. 145, where a metal rectifier is indicated. An alternative system using a full-wave valve rectifier is given in Fig. 146, and it will be seen that this is very similar to the previous one. Different methods of current regulation are shown in the two circuits, a plain resistance being indicated in the first example and a pair of regulator lamps in the second. As a matter of fact the two systems of regulation are interchangeable and produce the same effect—that is, they ensure that the charging current shall remain reasonably constant irrespective of the state of charge of the accumulators. To explain this point more fully it may be stated that when an accumulator is well "down" its internal resistance is comparatively high, but after it has been partly charged the resistance falls off. In consequence of these varying conditions, the charging current—if regulators were not employed—would be low when the batteries were first connected, and would gradually increase as charging progressed. This would be harmful to the accumulators.

Reducing the Charging Rate.—It is obvious that, if a charger is designed to supply, say, 27 volts to charge ten cells, the voltage would have to be reduced when only eight or five cells were in circuit. One method of reducing the voltage is to replace the fixed regulator resistance by a variable component or by a series of fixed resistances in series with tappings between them. This certainly gives the desired effect, but it is not economical, since the drain on the A.C. supply remains constant irrespective of the number of cells on charge. A much better method is that illustrated in Fig. 146, where the secondary winding of the mains transformer is tapped to provide varying voltages. The exact point at which the tappings must be made depends on the particular rectifier in use, but for a metal rectifier such as the Westinghouse L.T. 6 (max. output, 9 volts at 2 amps.), and when using the regulator resistance shown in Fig. 145, tappings should be made at 7·5 and 9 volts, the whole winding giving 11 volts. When using a Philips 451 full-wave valve rectifier (max. output, 8·1 volts, 1·3 amps.) in the circuit given in Fig. 146, the secondary winding should supply 16 volts on each half, and tappings should be taken at about 12 and 9 volts respectively. It will be found most convenient to arrange a rotary switch or a series of sockets for changing from one secondary voltage to another, and

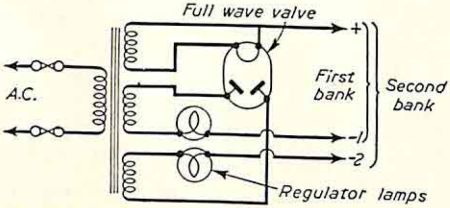


FIG. 148.—Two banks of cells can be charged at different rates from an A.C. supply by using the above circuit.

these arrangements are shown in the two circuits under discussion, and illustrated in Figs. 145 and 146.

It need scarcely be stated that the two arrangements considered can be applied to any required charging voltage and current by making a suitable choice of rectifier and transformer. The regulator lamps or resistance would also have to be chosen according to the rectifier, but particulars regarding this point are always supplied by the makers of the rectifiers.

Double-output Arrangements.—It is very often desirable that one should have two charging circuits, one to charge at a higher rate than the other. That supplying the lower current is used for small accumulators or any which have become slightly sulphated and therefore require to be given a slow charge, and the other is used for larger batteries which are in normal condition. When charging is from a D.C. supply this can be arranged quite easily by having two parallel circuits, as shown in Fig. 147. One of these contains a higher value of resistance than the other, and both resistances can be varied to obtain exactly the current required.

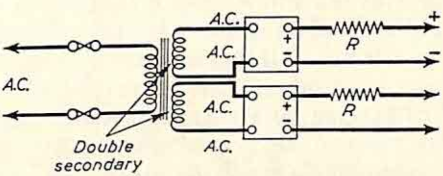


FIG. 149.—An alternative method of charging two banks of cells from a single full-wave rectifier. The full output of the rectifier can be obtained by joining the two negative leads together.

The method is rather different when the supply is A.C., but the circuits given in Figs. 148 and 149 can be used with success. The former circuit uses two metal rectifiers, each fed from a separate transformer winding, and the latter makes use of a full-wave valve rectifier with similar secondary windings to those used in the circuit in Fig. 146.

In the case of the valve rectifier there is a common positive lead and two separate negatives, but a single-charging circuit which will give an output equivalent to the maximum rating of the full-wave can be obtained by connecting the two negative leads together; the circuit then becomes identical with that in Fig. 146.

Power transformers suitable for any of the A.C. circuits described can be bought ready-made, or they can be made at home. It is obviously impossible to give particulars here, because the design of the transformer must depend largely on the type of rectifier employed, and also on the charging voltage and current required. These latter details will be found on the makers' instruction sheets, however, so that all constructional details can easily be worked out. There is one point which is worthy of mention, which is that, when using a valve rectifier, it will often prove more convenient to employ one transformer for supplying the higher (charging) voltage and another for the valve filament or heater supply. By this means it is possible to use smaller transformer cores, and so to simplify the constructional work.

Charging H.T. Accumulators.—Although transformers are nearly always required when charging low-tension accumulators from the mains, they can be dispensed with when dealing with H.T. accumulators of the type used for wireless purposes. When these are connected in series to a total voltage of 120 to 150 they can be charged from A.C. merely by inserting a metal rectifier between them and the mains point. The charging current will not generally exceed about 200 milliamps., and therefore an ordinary rectifier of the kind used in larger types of battery eliminators can be employed. In using an arrangement such as this, great care must be taken to ensure that adequate insulation is provided between the accumulators and earth, and a 0·5-amp. fuse should be included in each mains lead.

No reference has been made to the use of converters and dynamos, because the output will be D.C. and equivalent to a D.C. mains supply.

As a final note, when it becomes necessary to change the acid always use a reliable brand of acid such as B.A.A. This is guaranteed to be of correct specific gravity. In mixing acid, always add the acid to the water, not the water to the acid; in the latter case violent chemical action may cause serious acid burns to the skin, face, etc. Use only distilled water for topping up.

XXII

MODERNISING POWER HOUSE WIRING

Power points are more than ever necessary in the home, seeing that almost every day a new electrical appliance makes its appearance. But there are still many householders who put up with separate sizes and types of power points when they could quite easily standardise on one universal type of socket for all purposes at no great cost.

As most people know, there are two classes of power point

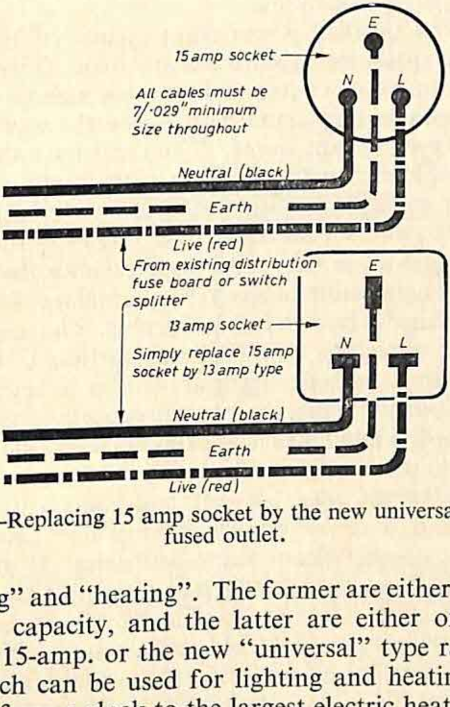

E
15 amp socket
N
L
All cables must be 7/·029" minimum size throughout
Neutral (black)
Earth
Live (red)
From existing distribution fuse board or switch splitter
E
13 amp socket
N
L
Simply replace 15 amp socket by 13 amp type
Neutral (black)
Earth
Live (red)

Fig. 150.—Replacing 15 amp socket by the new universal 13 amp. fused outlet.

—"lighting" and "heating". The former are either of 2-amp. or 5-amp. capacity, and the latter are either of the old-fashioned 15-amp. or the new "universal" type rated at 13 amp., which can be used for lighting and heating on any appliance from a clock to the largest electric heater.

If you have any 2- or 5-amp. power points in your home resolve here and now that you are going to do away with them at the earliest opportunity. They are limited in their usefulness, and you can only use them for appliances that take little current. In fact, the largest appliance you can use from a 5-amp. socket is one of 1,000-watt loading, and this not mean that you can plug in 1,000-watt appliances into *every* 5-amp. point in your house! Each lighting circuit (and there are usually not more than two in most six-roomed houses) is limited to a maximum load of 5 amps.

As long as you put up with old-fashioned power points you will not have complete interchangeability in your power-point system, nor will you have that flexibility and convenience which an adequate number of "universal" power points brings into the home.

A properly planned power-point system enables you to plug in any appliance anywhere at any time. Once you have a power-point system fitted with the new standard 13-amp. universal sockets throughout you are on the way to having real convenience in the home. You can't have this if some of your appliances will only plug in to "lighting" power points and others only into "heating" power points. The 13-amp. plug and socket is the power point of the future—you can forget the others. The chief reason is that it can be used for the connection of any kind of appliance (up to 3,000 watts), as it carries its own fuse in the plug. The second is that it is of the three-pin type (for safe earthing). Unlike 2-, 5- and 15-amp. sockets, which are still to be found in both two- and three-pin types, the 13-amp. socket is only available in the three-pin type, and it always has safety shutters over its live sockets.

Existing Power Points.—If your house was built after 1930 it will already have some power points in it, probably one each in the principal rooms and bedrooms. If these are of 15-amp. type you can make a start by replacing them with 13-amp. sockets. *Warning—you can't do this if they are only 5-amp. power points.* If the old sockets are of the three-pin type this should be easy as the wiring can be connected in exactly the same way, i.e., red ("live") to right-hand contact —as seen from the front—black (neutral) to left contact, earth wire to top contact (see Fig. 150). But check up that the "polarity" of the supply is right in case the wiring has been transposed. You can do this with a test lamp consisting of a plastic lamp-holder wired up with two stiff wires (1/0·004-in. V.R.I. cable will do). Put a suitable bulb in the lamp-holder and test out like this with the current on to the socket:

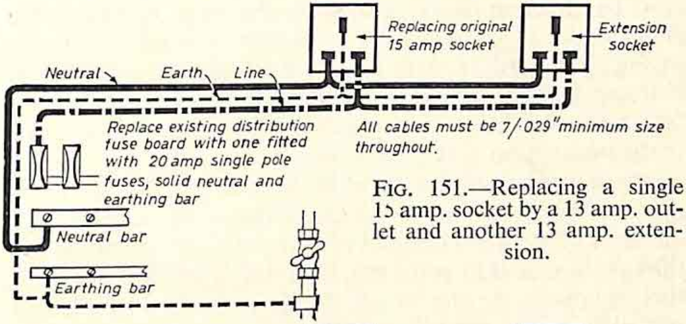

Replacing original
15 amp socket
Extension
socket
Neutral
Earth
Line
Replace existing distribution fuse board with one fitted with 20 amp single pole fuses, solid neutral and earthing bar
All cables must be 7/·029" minimum size throughout.
Neutral bar
Earthing bar

FIG. 151.—Replacing a single 15 amp. socket by a 13 amp. outlet and another 13 amp. extension.

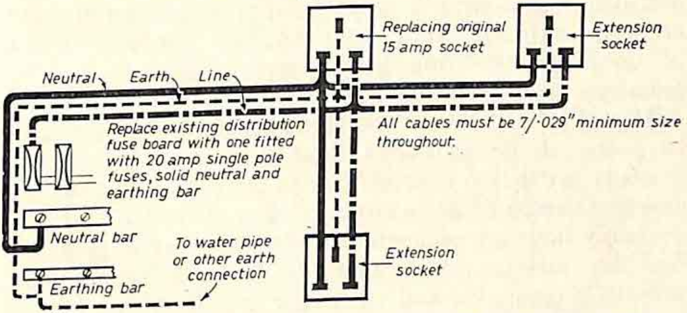

Replacing original
15 amp socket
Extension
socket
Neutral
Earth
Line
Replace existing distribution fuse board with one fitted with 20 amp single pole fuses, solid neutral and earthing bar
All cables must be 7/·029" minimum size throughout.
Neutral bar
Earthing bar
To water pipe or other earth connection
Extension
socket

FIG. 152.—Replacing one 15 amp. socket with a 13 amp. outlet and two 13 amp. extensions.

Test between left and right-hand contact—lamp should light.

Test between left and top contact—no light.

Test between right hand and top contact—lamp should light.

Replacing 15-amp. Two-pin Sockets.—If your wiring was carried out about twenty-five–thirty years ago you will probably find that all your power points are of the two-pin type, which are now obsolete, and in fact are considered today to be dangerous to use. Two-pin sockets have only red and black wires supplying them and no earth connection of any kind whatsoever. If you replace them by three-pin sockets a new earth wire must be run individually from each of them to connect the third pin to earth. The earth wire must be of the same size at least as the wires supplying the old socket. If you stick to 7/0·029-in. size you can't go wrong. The earth wire may be bare or lightly insulated, and if it can be run alongside the existing cables so much the better (see Fig. 150). If there is no main earthing connection in the installation make one yourself with a strong earth clip on the main water-pipe, fitted as close as possible to where it enters the house and on the *street side* of the stop valve, if any (Fig. 151). Best check up with your Electricity Board first though, in case they want you to connect your earth wire to their service cable sheath. If the water service pipe is connected to a non-metallic street main you obviously cannot use it for earthing. Your water authority can tell you this. In any case after fixing make the same check for correct polarity as you would for a three-pin socket replacement.

More Power Points.—Very few people can say that they have enough power points in their homes. If you can honestly say that you never have to use a two-way adaptor and that you can plug in any appliance anywhere, then you probably have an adequate installation—that is until you find that you want to use an electric blanket, a bedside lamp, a radio, a tea-maker and an electric fire all at once off two power points in the bedroom!

Few people have even two power points in each room. Most have only one. A lot have none at all. This chapter is intended to help the first two.

Supposing then you have just one 15-amp. power point in each room and you would like to double their number start by examining the wires behind the power points and see what size they are. If there are only three strands in each cable you can't do anything about it, as the conductors are not big enough to carry any more current. If, however, there are *seven* strands in each cable, then it is bound to be 7/0·029-in. cable, which has a rating of 20 amp. In that case you can "double up" by fitting *two* 13-amp. sockets to that circuit in place of the 15-amp. point either in the form of a twin socket or else by adding a second 13-amp. socket at any desired point (see Fig. 151). There are two provisos here: first of all, the second socket must be in the same room and the extension *must* be in 7/0·029-in. cable throughout.

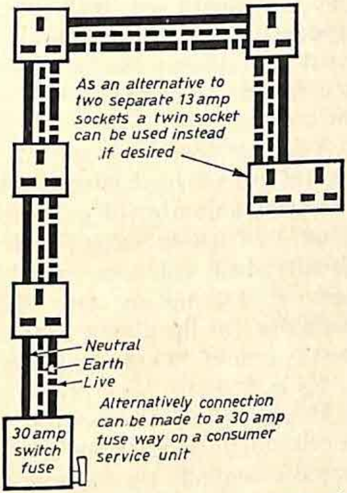

As an alternative to two separate 13 amp sockets a twin socket can be used instead if desired
Neutral
Earth
Live
Alternatively connection can be made to a 30 amp fuse way on a consumer service unit
30 amp switch fuse

FIG. 153.—A little known method of wiring six power points, each of 13 amps., from one 30 amp. switch fuse.

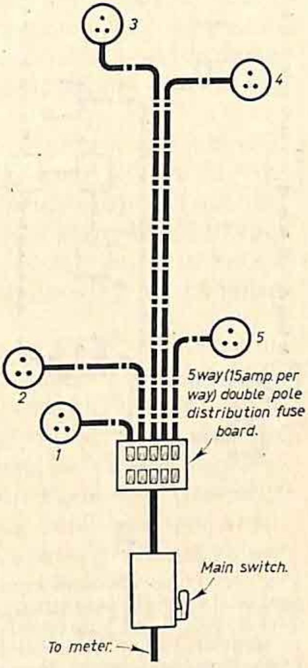


FIG. 154.—Conventional power wiring diagram for five 15 amp. sockets each on separate circuit and fused in line are neutral conductors.

You can in fact make that same circuit supply *three* 13-amp. sockets, but the three sockets must all be in the same room, which must not have a larger floor area than 200 sq. ft. (see Fig. 152). If it is a kitchen, however, your limit is *two* sockets only.

Whether you replace the single 15-amp. socket by two or by three 13-amp. sockets you will realise that the old 15-amp. fuse protecting the circuit may not be large enough to serve two and three 13-amp. sockets. The regulations cover this by permitting the 15-amp. fuse to be replaced by one with a maximum rating of 20 amp.

It will be seen that the old idea of one circuit for each power point is changing. Provided the cable is reasonably large enough to carry the largest load that might reasonably be expected and the circuit fuse is rated accordingly, more than one socket can be connected to the circuit.

A further development of the idea of using a single circuit for supplying a number of points is to use a 7/0·036-in. cable for the circuit which can then supply up to six 13-amp. sockets. The main fuse for the circuit in that case is one of 30 amp. capacity (see Fig. 153).

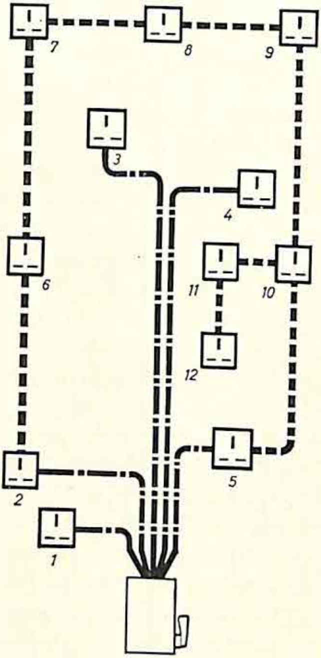


FIG. 155.—Conversion of conventional wiring to ring circuit. Sockets Nos. 2 and 5 are chosen to act as the beginning and end of the new ring circuit. Seven extra sockets are connected into the ring, two of them (Nos. 11 and 12) being fed by a "spur." Nos. 1, 3 and 4 now become spurs as well. Note: There is no limit to the number of points installed; for example, Nos. 1, 3 and 4 could each be extended to serve any additional sockets and twin sockets could be substituted for single sockets on Nos. 2, 5, 6, 7, 8, 9 and 10 if desired.

Using Circuit-breakers.—Electrical installation safety is based essentially on the means provided for automatically interrupting the current in any circuit should it reach dangerous limits. The fuse is the most common device used for this purpose, and it has the advantages of being simple and certain, provided, of course, that it is properly rated for the job it has to do. But a blown fuse is a nuisance, and it takes at least several minutes to replace it from the time it blows to the time the lights come on again. Even today millions of people haven't the foggiest idea how to replace a fuse. It does in fact need a certain amount of skill coupled with a little know-how to replace a fuse professionally.

The circuit-breaker does the same job as a fuse, and is instantly reset by merely turning a switch knob. Should a short-circuit or an overload occur the circuit-breaker "trips" and cuts off the current to the affected circuit with no fuss nor bother.

If you are troubled with frequent fuse blowings a circuit-breaker will make life easier for you—but it will not cure the trouble. A fuse blows because something is wrong—either an overload or short-circuit—so even if you replaced all your fuses with circuit-breakers you would still have black-outs. There is no remedy against "ropey" wiring but complete replacement.

If your installation was properly carried out and your electrical appliances and fittings were regularly inspected you might never know what it is to have a blown fuse. Still, when it does happen it is a nuisance, and the circuit-breaker has the great advantage that the supply can be restored instantly. Obviously before reclosing the circuit-breaker one must remove, switch off or disconnect the appliance, lamp, etc., which caused the fault—if it was a short-circuit—or reduce the load on the circuit if it was overloaded.

Circuit-breakers are used extensively by the Electricity Board on their distribution system. Miniature circuit-breakers which are used in domestic installations work on the same principle. You can buy Consumers Service Units already fitted with them instead of fuses—and incidentally the circuit-breakers come in very handy as main switches for each circuit, as they can be turned off by hand as well as automatically. Don't forget, however, that fuses will still have to be used in plug tops, such as the 13-amp. type, as so far no manufacturer has produced a circuit-breaker small enough to replace the cartridge fuse with which the plug is fitted.

XXIII

THE RING CIRCUIT

THE ring circuit is a modern system of house wiring which is simple, cheap and permits an unlimited number of appliances to be connected to one circuit. It is particularly suitable for the handyman to install. In the old system of wiring there was a fuse box "under the stairs", the sockets of each room of the house were connected each to a pair of fuses in the box. This is shown in Fig 156.

It will be readily appreciated how costly in material and time was this system, where every circuit had to run back to the fuse box.

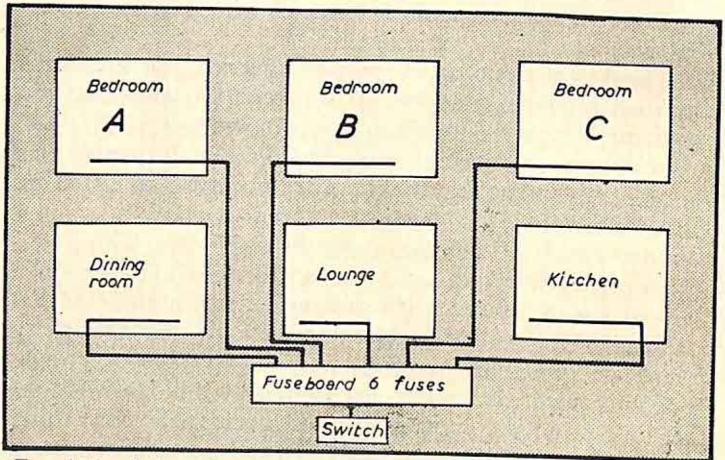


FIG. 156.—Schematic diagram of old system of wiring using separate circuits and fuses for each room. Number of 13A sockets restricted to two per circuit using 7/0·029 cable.

Now look at the ring circuit shown diagrammatically in Fig. 157. The multitude of fuses has gone. If the house is small (under 1,000 sq. ft.) there is only one fuse for all the power points. The wires are connected in a ring embracing all the sockets in the house. Because each point is supplied from both halves of the ring, the cable is smaller and cheaper than in the old system for a similar number of outlets. If any of the sockets are out of the way and involve a big extension to the ring a single connection called a spur is permitted as shown at X.

Range of Accessories.—A range of accessories has been designed especially for the ring circuit. The old trouble of different plug sizes has vanished; there is only one size of plug and socket in the ring circuit no matter what appliance

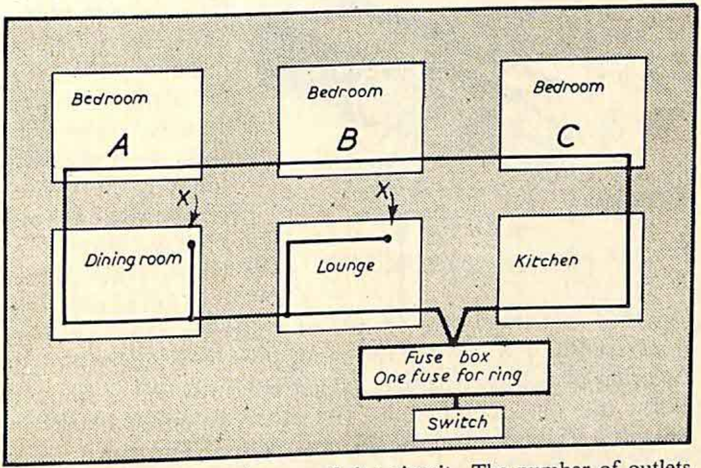


FIG. 157.—Schematic diagram of ring circuit. The number of outlets are unrestricted; install only one fuse and one size of socket outlet throughout the house.

is connected. Each plug has its own fuse inside it, so in case of trouble only the one particularly affected blows, and one does not have to search for the blown fuse in the fuse box as in the old days.

This, then, is the ring circuit in brief. Now to some practical details. In the first place, it should be said that the ring circuit is only suitable for A.C. circuits. It can be used to supply all kinds of fixed and plug-in appliances, with the exception of cookers and water heaters, which, because of their heavy loading, are wired separately from separate fuses.

The house lighting usually has its own circuits, which is advantageous in that light is available should the power circuit fail, but standard and table lamps can be plugged into the ring circuit as desired. This chapter is written on the assumption that the house is wired for lighting but not for power.

Cable.—In the schematic diagram, Fig. 157, the cable is shown as a single line. The actual cable will contain three conductors, and a connection will be taken from each one at every supply point.

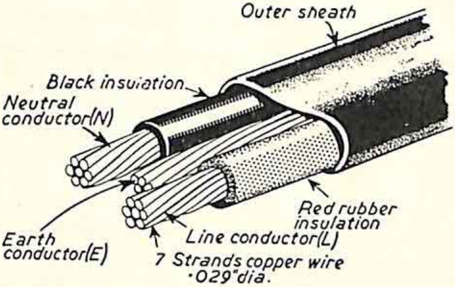


FIG. 158.—Two core and earth 7/0·029 T.R.S. cable.

Various wiring systems are in use—the most popular today is the tough rubber-sheathed (T.R.S.) system in which the three conductors are moulded into an outer sheath of rubber in the manner shown in Fig. 158. Two of the conductors have an additional covering of coloured rubber. That coloured red is known as the line or L conductor. The other, coloured black, is known as the neutral or N conductor. The third conductor has no additional insulation. It is known as the earth conductivity conductor or E. These identifications are most important, as will be shown later. The size of the cable for the type of circuit we are considering is specified by the I.E.E. regulations as 7/029, which means that each conductor will be made up of seven strands of copper wire 0·029 in. in diameter. The technical description for ordering this cable is 7/029 T.R.S. two core with earth conductor. Cables of similar construction, but in which the outer covering is made of plastic (P.V.C.) are also available. There is little to choose between the two, but rubber is perhaps easier to strip when connecting up. If your supplier has P.V.C. but not T.R.S. then use it.

Main Switch and Fuse.—The circuit must be protected by a switch and one 30-amp. fuse, which must be located somewhere near the incoming supply, but it should be placed in an accessible position so that fuses can be renewed without trouble when necessary.

Choice of the switch unit depends on any existing installation. Basically, where there is no other power wiring involved, protection of a ring circuit calls for a double-pole, 30-amp. switch with a fuse in one line only, as shown in Fig. 159. A double-pole fuse as used to be commonly employed is not now permitted.

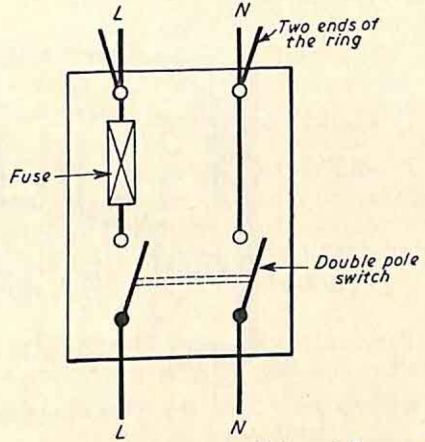


FIG. 159.—Diagram of switch and fuse required to control one ring circuit only.

If, however, other power circuits are already installed or will be installed in the future, the switch will need to be rated at 60 amps. to control them in addition to the ring. In this case, by far the best proposition is to purchase a "Consumer's Service Unit", a typical example of which is clearly shown in Fig. 160 (with cover removed). These have a 60-amp. main switch, and are available with any number of fuse "ways" up to eight. Thus, for example, a unit for the complete control of the electricity supply in a normal small house would have five fuses: cooker, immersion heater, ring circuit and lighting (two circuits). These units are quite inexpensive, and they give an appearance of neatness and tidiness. Two different types of fuse are available, cartridge and the rewirable. In the former, a blown fuse is simply replaced by another cartridge; in the latter, as its name implies, the fuse has to be rewired. The cartridge type has the advantage of simplicity and convenience, but the cartridges are naturally more costly than a length of fuse wire.

Socket Outlets.—The most-used accessory in the ring circuit is the socket outlet, and a special type is used, known as B.S. 1363 (its British Standard number). This takes a plug which has three flat pins—one larger than the other two —instead of, as the old types, having round pins. The plugs for use with these sockets contain a cartridge fuse, of which four ratings are available, 2, 5, 10 and 13 amps. Sockets embodying a switch are available, but in general they are unswitched. Sockets are arranged with shields over the live sockets, which open only when the plug is inserted. They are, therefore, quite safe where children are about. Socket outlets are made for surface or flush mounting. Surface-mounted types are easier to install. Flush types look better. Installation is simplified by the use of double units. Some typical socket outlets and a plug are shown in Fig. 161.

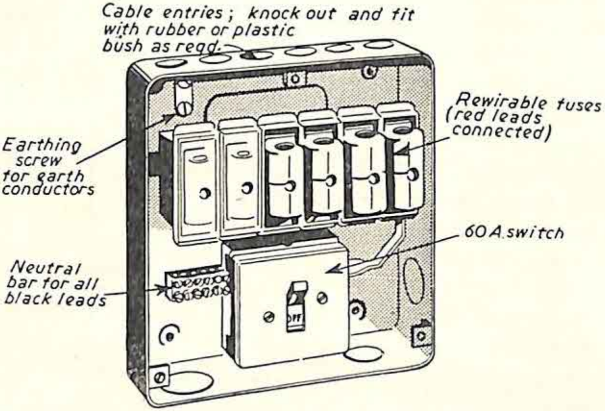

Cable entries; knock out and fit with rubber or plastic bush as reqd.
Rewirable fuses (red leads connected)
Earthing screw for earth conductors
60A switch
Neutral bar for all black leads

FIG. 160.—Typical consumer's unit.

In the case of flush-mounted sockets, it is not permissible just to cut a hole in the skirting board and drop them in. They must be fixed to a non-combustible box into which the wires are brought. Steel boxes as shown in Fig 162, are made to take all ring-circuit accessories. The box is fixed and, if necessary, recessed into the wall, so that the front plate of the socket just seats on to the skirting board. Before fixing, the appropriate "knock outs" for the cable entries are removed, and the holes "bushed" with rubber or plastic bushes to prevent abrasion of the cable. In general, socket boxes will require two bushed holes or three where a spur cable is to be connected.

Fixed Appliances.—There are some types of equipment, notably refrigerators, built-in fires and clocks, which are better permanently connected rather than supplied from a plug and socket. There are, therefore, two further ring-circuit accessories which must be used in such cases—the clock connector for clocks and any similar very small current devices and the fused spur box for other apparatus. The clock connector contains a 1-amp. fuse and provision for taking the light flexible cord usually supplied with clocks. In buying clock connectors make sure that they are ring-circuit type with terminals heavy enough to take 7/029 conductors.

The fused spur box is similar in principle to the clock connector, but it has provision for a 7/029 outgoing cable and has provision for similar fuses to those used in plug tops.

Fused spur boxes are available with and without switches. If there is a switch on the appliance there is no need to buy a switched spur box.

Junction Box.—In general, single-cable spur connections, such as shown at *X* in Fig 157, will be connected into the terminals of the nearest socket outlet. It may happen, however, that it is not convenient to do this, in which case a junction box is used instead. This is simply a moulded box in which are three terminals to which the "ring" conductors are brought as shown in Fig. 163. The spur is "teed" off from these. Note that the main ring conductor is not cut. Joints made simply by twisting or soldering cables without any screwed terminal are not allowed in any wiring.

Planning the Circuit.—The first thing to do is to ascertain the number of ring circuits required. I.E.E. regulations to which installations must comply, specify that there shall be one for every 1,000 sq. ft. of floor area, or part thereof.

Having settled the number of circuits, you should write to your local Electricity Board, stating that you propose to

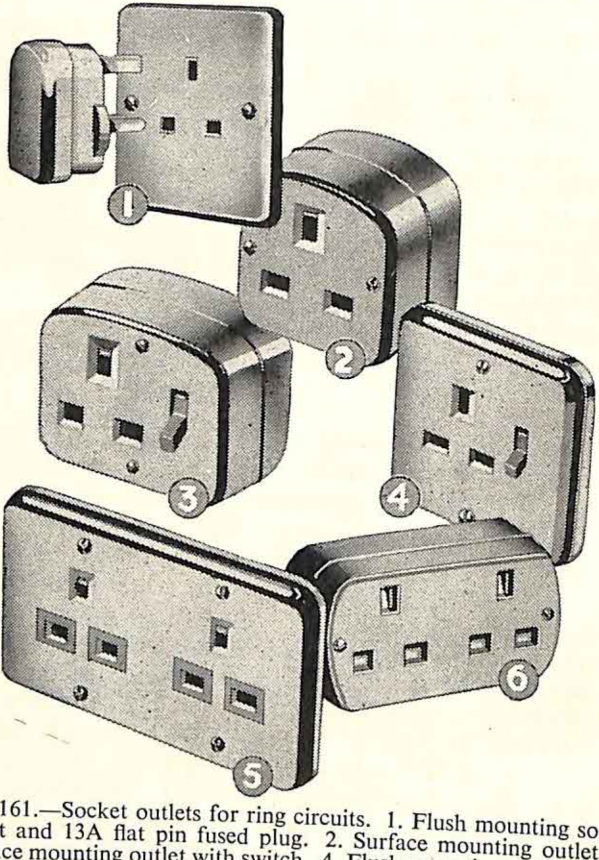


Fig. 161.—Socket outlets for ring circuits. 1. Flush mounting socket outlet and 13A flat pin fused plug. 2. Surface mounting outlet. 3. Surface mounting outlet with switch. 4. Flush mounting switched outlet. 5 and 6. Two-gang outlets for flush and surface mounting.

install so many ring circuits. Also, mention if you propose to install later, or have already installed, an electric cooker or immersion heater. The Board will then advise you if its existing cable from the roadway into the house is sufficient for the additional load, or whether you will be involved in any charges for heavier cable. Now comes the planning of the circuit. The following description is based on only one ring being necessary. If, because the floor is more than 1,000 sq. ft., two are necessary, I.E.E. regulations require that the socket outlets are reasonably distributed between the two. That is to say, don't wire it so that all the downstairs rooms, where most of the appliances will be used, are on one circuit and the lesser used rooms on the other.

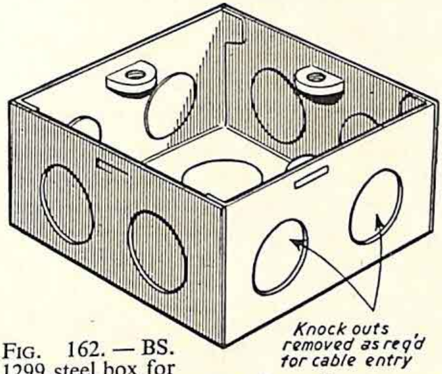


Fig. 162.—BS. 1299 steel box for flush-mounted outlets, etc. Boxes for two-gang outlets are also available.

Sockets Required.—First of all decide how many socket outlets are required in each room, and where they are to be located. Don't stint these. The beauty of the ring circuit is

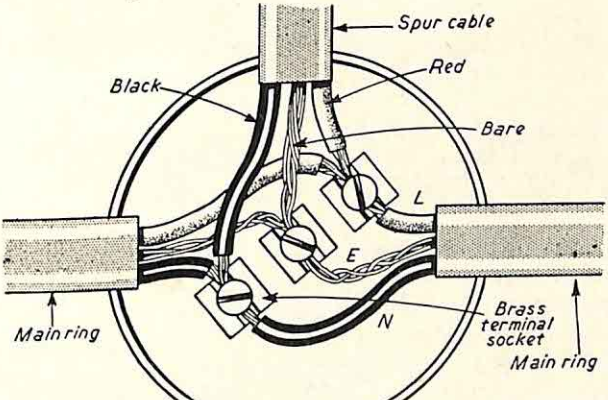


Fig. 163.—A junction box for spur connection.

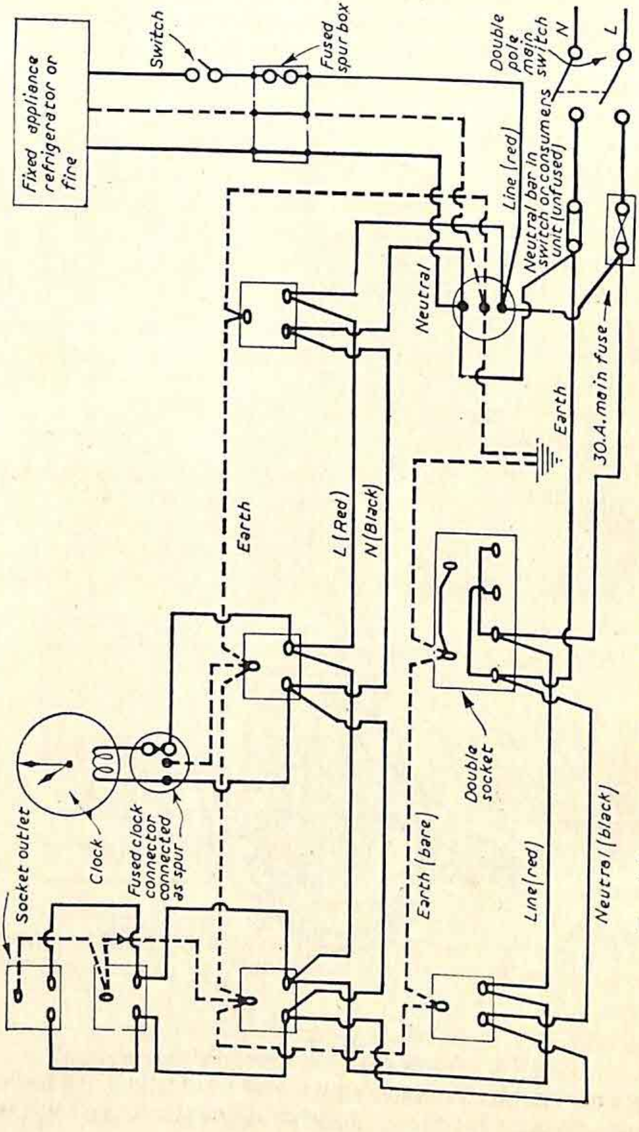


FIG. 164.—Wiring diagram for ring circuit showing the various accessories.

that practically no additional cost is involved other than the cost of the sockets. Write down how many appliances are likely to be in use at one time. In the lounge, for instance, there could be a fire, a clock, two standard lamps, radio, television, besides other appliances, all in use at one time. In a bedroom there could be a fire, a clock and two bedside lamps. Go over the requirements of each room, noting the number of socket outlets desired, and the best position for them. Try to avoid the need for long lengths of flexible cord for appliances trailing on the carpet. Socket outlets in bathrooms are absolutely prohibited under the latest regulations, but a fire may be permanently installed provided it is well out of reach of anyone, and is controlled by a cord switch fitted on the ceiling.

Permanently fixed appliances will need to be provided with fused spur boxes, and clock connectors for clocks. Now, by drawing a diagram, or on-the-spot inspection, determine the shortest and most convenient route for the ring so that it starts and embraces the majority of the socket outlets.

Socket outlets and spur boxes for fixed appliances which are outside the convenient run of the main ring can be fed by "spurs".

I.E.E. regulations require that not more than two socket outlets or one fixed appliance shall be fed from a spur, and not more than half the total number of points installed (excluding clocks) may be served by spurs. In general, it is better to connect as much as possible directly to the ring, and use spurs only where it is obviously wasteful of wire not to do so.

Because houses differ so much in construction, it is impossible to lay down any hard-and-fast rules for the lay-out of a ring circuit. A wiring diagram showing how the various accessories mentioned are connected is given in Fig. 164.

Practical Wiring.—We have now dealt with principles, materials and accessories, and there remains to be given some practical notes on wiring.

In the first place, if it is a new installation, you will not connect it to the supply. The Electricity Board engineers will do this after they have tested it. You will be required to leave two "tails" of single conductor 7/064 T.R.S. cable from the "live" side of your main switch of sufficient length to reach the supply intake.

From what has been said before, it will now be appreciated that the ring circuit consists of a loop of T.R.S. cable containing three cores—line (red), neutral (black) and earth (bare).

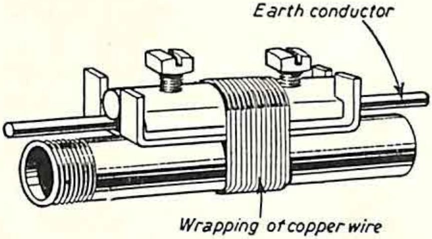
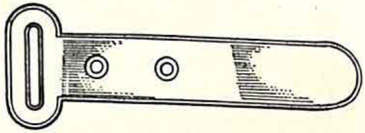


FIG. 165.—(*Left*) Earth clamp.

FIG. 166.—(*Right*) Buckle clip for securing wiring.



The guiding principles to remember right through the installation are these:

(1) The starting and finishing ends of each conductor of the loop will be brought together at the control unit.

(2) The line (red) conductor will be connected to these fuses in the control unit, and in the remainder of the red loop always to the terminal marked "L" in the socket outlets. This is the one on the right looking at the front of the outlet.

(3) When an appliance is connected permanently to the ring, through a fixed spur box, the "L" wire must be connected to the terminal associated with the fuse, and if there is a switch in the appliance, this must also be in the "L" lead.

(4) The earth conductor wire will be connected to the earth socket—the largest one—of all the socket outlets, to the metal casing of every metal fixed appliance, through

the connector box and to the earth terminal on the casing of the main switch or consumer's unit.

The earth terminal to which each continuity conductor is connected must itself be connected to an "earth" electrode—the water main is generally ideal for the purpose. Special clamps, such as that shown in Fig. 165, are available to ensure a good connection to the pipe. In this form of clamp, the pipe is first cleaned and the wire wrapped round just comfortably tight.

The two screws are then turned, which has the effect of tightening the loop and causing it to pull hard against the pipe.

On no account should the earth wire be connected to a gas pipe.

Earth Connection.—The earth connection must be made with 7/029 copper wire. (5) The neutral (black) wire will be connected to the non-fused terminal of the switch or control unit and of fused spur boxes.

As regards the actual wiring, circumstances differ in every case, and the best route for the wiring, the lifting of floorboards, the removal of skirting boards and passing along or through joists must all be dealt with as they come.

The cable should be kept away from gas pipes at all times, and the temptation to squeeze the cable into a slot already carrying a gas pipe should be avoided. The I.E.E. Regulations require that "in accessible position" the cable shall be supported at intervals of 9 in. where it runs horizontally and 15 in. where it runs vertically. Metal cable clips (buckle clips) are used for this purpose (see Fig. 166). Most of the wiring for a ring circuit will be run under floors, along and across joists. In the former case the cables should be fastened to the side of the joists, and in the latter holes should be drilled in the joists and the cable threaded through.

Concealed Cable.—Where a cable is to be concealed in a plaster wall, the brickwork should be recessed as necessary and a length of metal conduit set in the plaster and the cable drawn through. The conduit should be bushed with plastic bushes at each end.

In preparing the ends of a cable for connecting up, the rubber covering should first be removed by "nicking" round with a knife, and pulling the outer sheath away. Then the insulation of the conductors should be removed in a similar manner, leaving a length of conductor insulation projecting from the end of the rubber sheath.

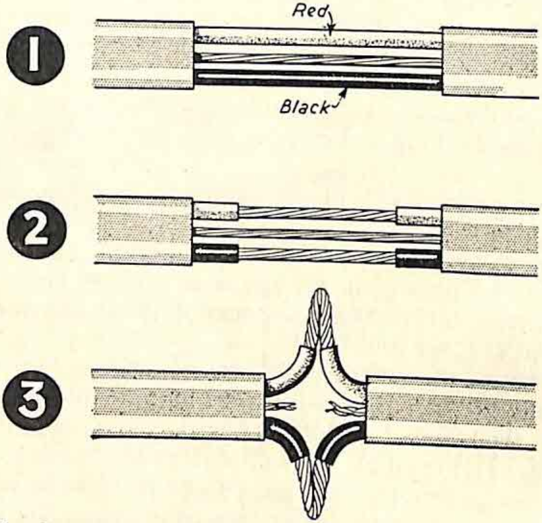


FIG. 167.—Connecting without cutting conductors. 1. Outer sheath removed. 2. Insulation removed from L and N conductors. 3. Bared portions twisted together to form lead to go in the terminal of the accessory. All ring-circuit accessory terminals are big enough to take a twisted loop like this and also another wire.

The best practice, and where the terminals in the various accessories permit, is to wire the ring as far as possible without cutting the copper conductors.

This is done by first removing the outer sheath from the cable near the point where the connection is to be made, then stripping off the insulation from the conductors for about 1¼ in. and forming each into a loop as shown in Fig. 167. These loops enter the three terminals of the outlet.

Cable in Fittings.—Do not pull cables tight into the fittings. It is better to leave a little slack in case of accidental cutting of the wire or to facilitate alterations or extensions at some future date. A cable without slack can be most difficult to remove when an outlet has to be replaced.

The fixing of surface-mounted sockets is not quite as straightforward as it appears at first sight, because the I.E.E. Regulations demand that where the sheathing of a cable is removed, as is, of course, necessary for connecting up, the termination must be in an enclosure of incombustible material.

A socket outlet fixed directly to a skirting does not provide such an enclosure because of the combustible wood. On the other hand, a socket fixed to a stone wall does comply.

It is only comparatively recently that accessories have become available which meet this regulation.

In some, a hollow-moulded "pattress" is supplied which is first fixed to the skirting and the socket-outlet (or other accessory) mounted upon it. In other makes the "pattress" is replaced by a suitably shaped piece of sheet insulation about $\frac{1}{16}$ in. thick. If you find that neither of these is available for the accessories you propose to buy, then you should obtain a sheet of yellow or brown insulating board as used for radio work, or a piece of asbestos board and make your own mounting plates.

Board Should be Advised.—When the installation is complete, the Electricity Board should be advised and asked to come and test it. The inspector will bring the necessary instruments to test the continuity of the conductors, the efficacy of the earthing arrangements and the insulation resistance of the installation. If the work has been carried out carefully in accordance with these instructions, and using ordinary common sense, there should be no trouble.

It is possible, however, that the inspector will find some minor faults, but in general he will authorise the switching on of the supply without waiting for you to make the required alterations, provided you do so within a specified time.

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